PALYNOLOGY OF THE PALAEOCENE AND EARLY EOCENE OF THE LONDON BASIN.

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Thesis submitted for the degree of
Doctor of Philosophy in the
University of London.

April, 1982.

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ABSTRACT.

To date no detailed examination of the spore/pollen content of the Thanet Beds and Woolwich and Reading Beds (late Palaeocene) of the London Basin has been undertaken. The present investigation aims to record the diversity in the plant microfossils (particularly miospores) present in the late Palaeocene to early Eocene deposits of the London Basin; to determine their geographical and stratigraphical distribution; and to compare the microfloras with those previously described from adjacent areas of northwest Europe, the North Sea Basin and North America.

Samples were examined from nine main sections which include the Thanet Beds, various facies of the Woolwich and Reading Beds, the Blackheath and Oldhaven Beds and the London Clay. Part of the sequence at Alum Bay, Isle of Wight (the Reading Beds to basal Bracklesham Beds) was also studied for comparison.

In all two hundred spore/pollen taxa are distinguished, ten of which are new species, twenty are identified only to generic level and at least thirty-five are considered to be reworked.

The presence of dinoflagellate cysts, acritarchs and other algae is also recorded although no detailed taxonomy is given.

Although most of the spore/pollen taxa present occur throughout the strata examined it has been possible to recognise a series of microfloral associations based mainly on changes in relative abundance of both the miospores and the acid resistant microplankton. 1) Thanet Beds; a microflora defined on dinoflagellate cyst taxa, correlating with the northwest European Deflandrea speciosa Zone. 2) Woolwich and Reading Beds; two distinct, local spore/pollen floras; and one dinoflagellate cyst/pollen association, correlating with the Apectodinium hyperacanthum Zone of Costa & Downie 1976; 3) London Clay/basal Bracklesham Beds; two spore/pollen associations; a lower, reworked microflora and an upper one marked by the incoming of stratigraphically restricted taxa.

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ACKNOWLEDGEMENTS.

The early stages of this work were carried out during the tenure of a N.E.R.C. research studentship and a Thomas Witherden Batt Scholarship from University College London. Both awards are gratefully acknowledged.

The topic was suggested by my supervisor Professor W.G. Chaloner F.R.S. and I am extremely grateful for his help, encouragement and critical advice during the course of the study.

Many people have given invaluable technical assistance. I wish to thank particularly Professor W.G. Chaloner, Mr. C. King and Dr. A.D. Rundle for assistance in field work; Dr. C. Cave for advice and assistance in preparing samples for the transmission electron microscope; Professor W.G. Chaloner and Messrs. M. Gay, G. Lawes and P.D.Moore for operating the scanning and transmission electron microscopes; the photographic unit of the Department of Botany, Birkbeck College for printing some of the photographs and especially Mr. R.C. Packer for producing the final copies of the plates.

Thanks are also due to the Keeper of Palaeontology, Institute of Geological Sciences, to Mr. A.D. King and Dr. C. Crane for the provision of additional samples.

I am indebted to various colleagues for information and useful discussion, in particular Dr. K. Fowler, Mr. A.D. King, Mr. C. King and Dr. P.R. Crane.

This work was begun at University College London and I wish to thank Professor D. Lewis (then Head of the Department of Botany and Microbiology) and Professor T. Barnard (Head of the Department of Micropalaeontology) for the use of facilities in their respective departments. The work was completed at Paleoservices Ltd. (Watford) and I am very grateful to the Director, Dr. V.L. Roveda for his encouragement and for making available the company's facilities. Mr. T. Doran, Manager of Paleochem Ltd. (Watford), kindly provided facilities for copying the final manuscript. My sincere thanks go to Lesley Adams, Ann Hardy and particularly Christine Langley who typed various parts of the manuscript.

Finally, this work could not have been completed without the support and encouragement of my friends and my colleagues at Paleoservices Ltd.

INTRODUCTION.

While early Tertiary spores and pollen from the Continent are very well known, particularly from Germany, Belgium and France, there have been comparatively few studies of equivalent deposits in southern England (Chapter 3). These include the important contributions of Sein (1961) and Pallot (1961). Their work is based on comparisons with the pollen of extant genera and with contemporaneous fossil macrofloras. Both interpret the fossil assemblages in terms of present day climate and vegetation. Gruas-Cavagnetto (1976a) records a diverse microflora from some 24 isolated samples from the late Palaeocene to Oligocene of southern England and lists stratigraphically significant species. She also reports briefly on the Woolwich Beds microflora from Swanscombe (1970). Fowler is currently investigating Eocene sediments of the Hampshire Basin.

Thus, to date, no detailed examination of the spore and pollen content of the Thanet Beds and Woolwich and Reading Beds of southern England has been undertaken.

From the close similarity between the early Tertiary deposits of southern England and adjacent areas on the Continent (Chapter 1) one would expect that the microfloras of both areas would be very similar. The main aim of this investigation therefore, is to describe in detail, for the first time, the spores and pollen present in the Woolwich and Reading Beds, as part of a more extensive study of spore/pollen floras of the late Palaeocene to early Eocene (Thanet Beds to London Clay) of southern England. Particular attention is also paid to the Woolwich and Reading Beds since, with their marked facies variations, there is potential for the recognition of distinct, facies controlled, microfloral associations.

During the initial stages of the study it was hoped that some species would prove to be stratigraphically restricted and of value for correlation. It became apparent, however that the majority range throughout the formations examined and the very few that are at all limited are extremely rare (Chapter 5.3 section 4).

Dinoflagellate cysts have been of much greater value for correlation within the Tertiary. Their distribution in southern Englamd, from the Thanet Beds to the London Clay, is already well documented from the work of Williams (1963), Hussain (1963), Costa & Downie (1976) and Denison (1977) (Chapter 1.2 and Chapter 3.2). In the present work dinoflagellate cysts, acritarchs and other algae are only treated at a superficial level. No detailed taxonomy is given, they are recorded as broad morphologial groups similar to those recognised by Downie, Hussain & Williams (1971) and by Denison (1977). These are invaluable for environmental interpretation. The dinoflagellate cyst zones previously recorded in the Thanet Beds and Woolwich and Reading Beds are recognisable but only the Dracodinium solidum (Costa & Downie 1976) Zone is distinguished in the London Clay.

Sections have been studied along an east-west line across the London Basin, from Pegwell Bay in the east to the Newbury area in the west. These include all facies of the Woolwich and Reading Beds as well as Thanet Beds and London Clay. The Leaden Roding Boreholes from Essex give the most northerly samples of Reading Beds and a more complete section of London Clay than is now available from Herne Bay. Spot samples were collected through the London Clay at Alum Bay (Isle of Wight) for comparison with the more marine sequence from the London Basin.

Palynological analysis of these samples has given a moderately rich and diverse microflora which compares well with those previously described on the Continent. Over 200 species of spores and pollen are recognised, including reworked forms.

From the results of the quantitative analysis of spores/pollen and microplankton/algae, a series of distinct microfloral associationsis identified. In spite of these quantitative variations the spore/pollen assemblages from the Thanet Beds to the lower half of the London Clay are considered to be part of a single microfloral unit. The local facies differences result from the distribution patterns of the parent plant communities and sedimentological processes during deposition.

The only significant change in the microflora occurs near the top of the London Clay at Alum Bay and continues through the basal Bracklesham Beds. Here several stratigraphically restricted species appear although they are rare and form a minor part of the total microflora.

This investigation therefore provides new data on the detailed distribution of spores and pollen in the late Palaeocene and early Eocene of southern England and confirms the stratigraphic value of the dinoflagellate cysts already known from the literature. Stratigraphic markers amongst the spores and pollen are few however, and are sporadic in occurrence. New forms appear towards the top of the London Clay but are comparatively rare.

The data presented here confirm the general unity of the flora of southern England and adjacent areas on the Continent during the late Palaeocene and early Eocene. Quantitative variations in the microflora of the Woolwich and Reading Beds point to the existance of local plant communities whose spores and pollen dominated the microfloras accumulating in the vicinity.

CHAPTER 1. GEOLOGICAL BACKGROUND.

1.1 DISTRIBUTION OF TERTIARY STRATA IN AND AROUND THE BRITISH ISLES.

This investigation deals with the palynology of the Palaeocene and early Eocene rocks of the London Basin, one of the largest areas of Tertiary outcrop in the British Isles. Recent exploration in the shelf seas surrounding Britain has shown that the on-shore Tertiary sequences represent only a small part of thick, widespread Tertiary deposits which extend across the North Sea Basin and the English Channel into north-west Europe.

In this chapter the distribution and age of the various Tertiary deposits in and around the British Isles are briefly reviewed. (Fig. 1.1, after Curry, Adams, Boulter, Dilley, Eames, Funnell and Wells 1978).

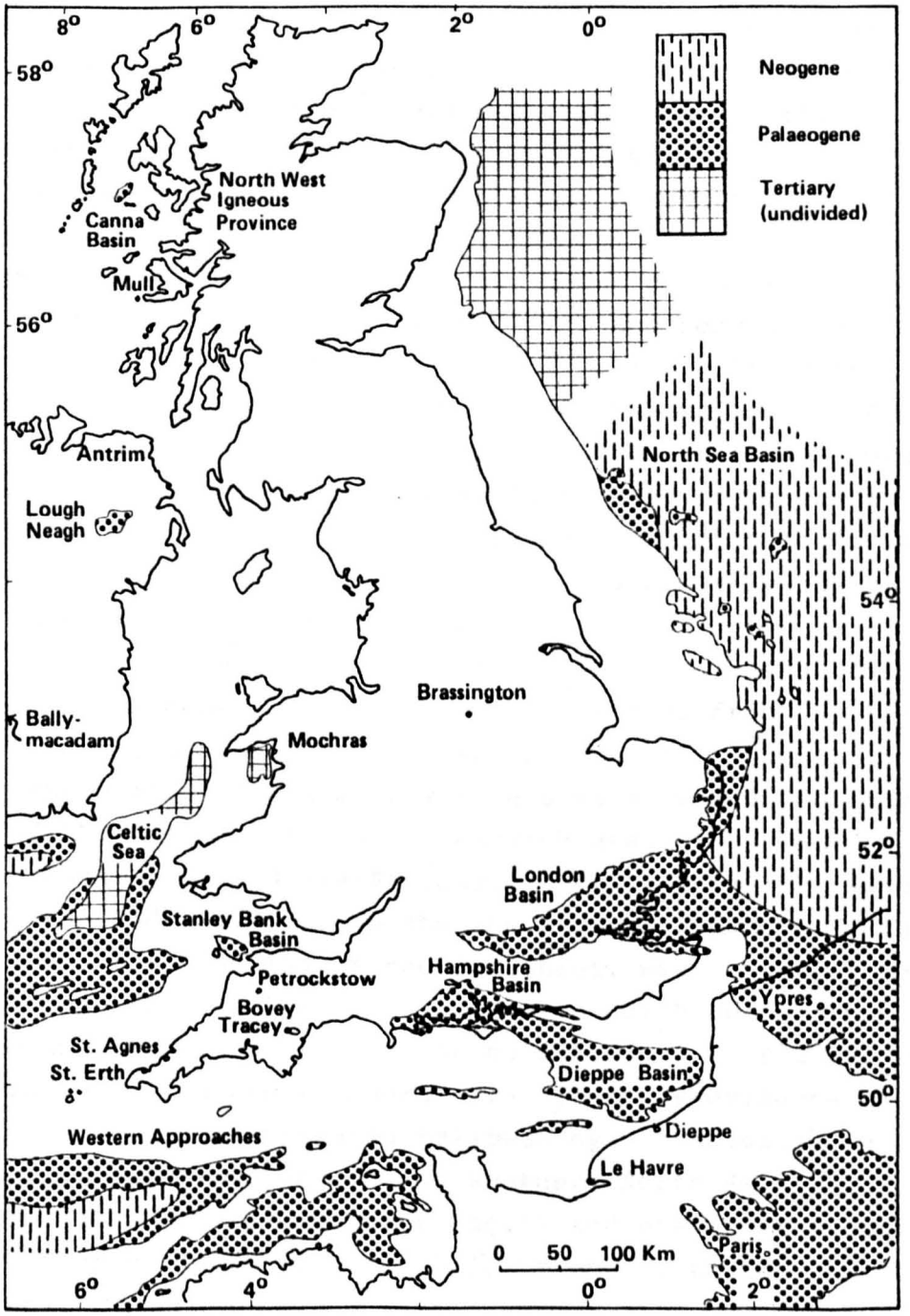
The largest areas of outcrop of Tertiary sedimentary rocks are concentrated in southern England; the London and Hampshire Basins, with the third largest area, the Lough Neagh outlier, in northern Ireland. Smaller, isolated deposits occur elsewhere including Devon, Cornwall, Derbyshire, East Anglia and, as interbasaltic sediments, in the Tertiary igneous province of north-west Britain.

The onshore Tertiary succession is incomplete having several stages absent or only represented by thin deposits. The earliest stages, Danian and Montian, are absent and the oldest Tertiary deposits are the Thanet Beds (Thanetian) which rest unconformably on the Senonian Chalk in the London Basin. The rest of the Palaeocene and some of the Eocene are present there (Woolwich and Reading Beds to Bagshot Sands) but the latest Eocene and Oligocene stages are not represented in the London Basin (Fig.1.2).

The Palaeogene sequence in the Hampshire Basin is more complete. Although the Thanet Beds are absent the overlying succession contains deposits of Late Palaeocene to early Middle Oligocene age (Reading Beds to Hamstead Beds, Hamstead Formation of Curry *et al*. 1978).

The sediments of the London and Hampshire Basins have long been considered to have been laid down in a more widespread basin of deposition, the Anglo-Franco-Belgian Basin

Figure 1.1



DISTRIBUTION OF TERTIARY ROCKS IN AND AROUND BRITAIN (after Curry et al. 1978)

of Stamp (1921) or Anglo-Paris-Belgian Basin of Curry (1967). Borehole evidence from the English Channel confirms the continuity of deposits through this area. Curry (1962) describes an outlier between the Isle of Wight and Cherbourg which contains a sequence of Reading Beds, London Clay and Bracklesham Beds comparable with sequences in the Hampshire and London Basins. More recent work (Auffret et al. 1975, Curry & Smith 1975) has shown a south-easterly continuation of deposits from the Hampshire Basin towards Dieppe, the Dieppe Basin(Fig. 1.1), which contains Thanetian limestones, equivalents of the Woolwich and London Clay Formations, the Bracklesham Group and possibly the Barton Formation (Curry et al. 1978, p.23). A smaller area of Palaeogene deposits which also contains probable Woolwich Beds and London Clay occurs about 75km north-west of Le Havre (Auffret & Gruas-Cavagnetto 1975). The succession there is thinner than that in the Dieppe Basin and probably contains non-sequences (Curry et al. 1978).

Knox & Ellison (1979) and Knox & Harland (1979) describe a Palaeocene to early Eocene ash-series from the North Sea, Denmark, northern Germany and north-east Netherlands and compare and correlate it with a similar deposit at the base of the London Clay in the Harwich area of the London Basin. Knox & Harland (1979) conclude that during the late Palaeocene and early Eocene the London and Hampshire Basins, and neighbouring basins on the Continent, were areas of deposition on the margins of an extensive North Sea Basin, consequently they contain sequences which are less complete than those in the central North Sea. There is evidence of a late Palaeocene regression followed by a transgression which extended first across the southern North Sea area, Germany, the Netherlands, East Anglia and eventually across the rest of southern England, Belgium and northern France (see page 36 below).

Kent (1975) summarises data on the Tertiary deposits of the North Sea Basin. Sediments were deposited in a single, unfaulted, subsiding basin which trends north to south, swinging to the south-east, towards the Netherlands, in the southern part. The complete Tertiary sequence is thickest in the central North Sea, close to the Ekofisk Field

(56°40'N 3°20'E), where 3,500m have been recorded (Heybroek et al. 1967) of which 1,400m are Palaeogene including 400m Palaeocene, and 700m Eocene (Curry et al. 1978, p.24). In the central North Sea the Tertiary begins with Danian chalks followed by Palaeocene sands, particularly on the western side of the basin. Various environments of deposition have been suggested for these sands but their origin remains controversial; they may represent off-shore bars, lobate deltas or turbidites. Most of the Eocene and later deposits are shales and in the central part of the North Sea depositon appears to have been continuous from Eocene to Pliocene times with progressive shallowing of the basin during the Neogene (Kent 1975, p.454, 455). Correlations within the basin are believed to be accurate but links with on-shore sequences are few since facies are often different (Curry et al. 1978, p.24).

As a result of recent work, particulary in palynology, the age of isolated Tertiary deposits in south-west England is now better known.

The Petrockstow and Bovey Basins (Fig. 1.1), which contain non-marine Tertiary sequences, are fault-bounded depressions along the Greencliff-Sticklepath-Lustleigh-Torquay wrench fault zone (Edwards 1976, p.17). The same fault line extends north westwards into the Bristol Channel and bounds another Tertiary basin north-east of Lundy Island, the Stanley Bank Basin (Fletcher 1975, Boulter & Craig 1979). Palynological analyses of borehole material from these basins have shown them all to be Oligocene in age in their highest deposits, while some of the deeper, undated deposits may be Eocene in part (Curry et al. 1978, Wilkinson et al. 1980). Thus the Petrockstow deposits range from late Eocene to early Oligocene (C. Turner quoted in Curry et al. 1978, p.27); the highest 300m of the 1,200m sequence in the Bovey Basin have been dated as early to middle Oligocene (Boulter & Wilkinson 1977) and the highest 33.85m of a 340m sequence in the Stanley Bank Basin are also of middle Oligocene age (Boulter & Craig, 1979).

The small sand deposit at St. Agnes in Cornwall was previously believed to be Pliocene in age but that too has

been shown to be middle Oligocene by palynological studies (Boulter & Wilkinson 1977).

Only the youngest Palaeogene deposits occur in the Lough Neagh outlier, Ireland. Wilkinson et al. (1980) date the upper part of the sequence, Lough Neagh Clays, as Chattian and the sequence as a whole as middle to latest Oligocene.

A Chattian age has also been determined for non-marine deposits which overlie Tertiary basalts in the Canna Basin, north-west of the island of Canna in the Sea of the Hebrides (Evans, Wilkinson & Craig 1979). This is the most northerly of the Oligocene basins containing non-marine deposits found on the western side of Britain so far.

A variety of dates has been suggested for the inter-basaltic sediments from this area. In Antrim and Londonderry Watts (1970) suggests they may be of Palaeocene age. Palynological studies of the interbasaltic deposits of the Isle of Mull however have suggested dates as diverse as Maastrichtian (Srivastava 1975) and Miocene or early Pliocene (Simpson 1961). Boulter (in Curry et al. 1978, p.30) suggests that a Palaeocene age is more likely and comments that this also agrees with ages deduced from radiometric evidence.

There is controversy over the age of the Tertiary deposits in the Llanbedr (Mochras Farm) Borehole. Herbert-Smith (1971) concluded that the lower part of the succession is middle Oligocene and the upper part early Miocene. Wilkinson & Boulter however, re-examined the material and tentatively dated the whole sequence as Chattian (late Oligocene) (quoted in Curry et al. 1978, p.28).

Seismic surveys in the Celtic Sea indicate the presence of well-bedded rocks which overlie dated Upper Cretaceous beds and are believed to be mainly Palaeogene in age (Curry et al. 1978, p.23). These deposits are still poorly known, dates of early Eocene and late Eocene or Oligocene are reported from two separate localities by Warrington & Owens (1977) and they also report Miocene sands from a core in an area about 120km north-west of the Scilly Isles.

Widespread Palaeogene deposits occur in the western approaches of the English Channel (Fig. 1.1) and include

deposits of Danian to Oligocene age (Curry et al. 1965, (1970).

Although extensive Neogene deposits are reported from the North Sea Basin (Kent 1975), Neogene outcrops in the British Isles are very limited in their stratigraphical range and geographical extent. They occur in Kent (Lenham Beds, late Miocene), East Anglia (Coralline Crag, late Pliocene), Cornwall (St. Erth Beds, age uncertain possibly late Pliocene) and Derbyshire (Brassington Formation, Miocene to Pliocene boundary) (Curry et al. 1978).

Thus, although the Palaeogene sediments of the London Basin form one of the largest areas of outcrop of Tertiary strata in the British Isles, they represent only a small portion of the total Tertiary sequence. The area is important however since it contains the complex sedimentary sequences, with stratigraphical breaks and diverse facies, characteristic of deposition at the margins of a large sedimentary basin. The faunas and floras may contain elements from both the marginal facies and the main basin which may enable correlations to be made between them (Curry et al. 1978, Knox & Harland, 1979).

1.2 CORRELATION OF EARLY TERTIARY DEPOSITS OF SOUTHERN ENGLAND AND NORTH-WEST EUROPE.

In this section various aspects of the problems of correlating early Tertiary deposits of Britain and north-west Europe are considered briefly.

Correlation between the early Tertiary deposits of southern England and adjacent areas of north-west Europe has always been difficult and remains controversial. Most difficulties arise from the present geographical isolation of Tertiary sediments which were originally laid down in a single basin of deposition but which have become separated as a result of post-depositional folding and erosion. Furthermore, these shallow marine and non-marine sediments show considerable lateral changes in facies which make litho-stratigraphical correlations difficult. Many of the fossils

Figure 1.2

FIGURE 1.2 RELATIONSHIPS BETWEEN VARIOUS MICROFOSSIL ZONATIONS AND THE EARLY TERTIARY DEPOSITS OF THE LONDON BASIN AND THE ISLE OF WIGHT.

THIS IS A COMPOSITE DIAGRAM BASED ON TWO DISTINCT CORRELATIONS:

(i) Correlation of the planktonic foraminiferid and calcareous nannoplankton zonations after Hardenbohl & Berggren (1978).
   - A after Bolli (1957a, b, c, 1966) and Stainforth et al. (1975).
   - B after Blow (1969) and Berggren & Van Convering (1974).
   - C after Martini & Worsley (1970), Martini (1970, 1971) and Muller (1974).

(ii) Correlation of dinoflagellate cyst zones with calcareous nannofossil zonation and with the lithostratigraphic units of southern England, after Costa & Muller (1978) with modifications to the lithostratigraphy after Curry et al. (1978) and King (1981).

CONTROVERSIAL LEVELS WITHIN THE PALAEOCENE AND EARLY EOCENE.

a* Haq & Lohmann (1975) correlate the base of the M. valascoensis and NP9 (D. multiradiatus) Zones.

b* Haq & Lohmann (1975) place the base of the M. edgari Zone below the base of the NP10 (M. contortus) Zone. Caro et al. (1975) place it higher, above the base of NP10. Bignot & Moorkens (1975) do not recognise a M. edgari Zone but place this junction (top M. valascoensis Zone) above the base of NP10. Curry et al. (1978) correlate the base of P6 with the base of NP10.

c* Haq & Lohmann (1975) place the base of the M. subbortinae Zone below the base of NP11 (D. binodosus), Caro et al. (1975) place it above the base of NP11.

d* Caro et al. (1975) place the base of the G. formosa formosa Zone within NP11. Bignot & Moorkens (1975) tentatively place it higher, within NP12 (M. tribrachiatus) as does King (1981).

e* Curry et al. (1978) correlate the base of P8 with the base of NP13 (D. lodoensis) Zone.

BASE OF THE EOCENE:

v* At the base of M. edgari, NP10 (M. contortus) and Wetzeliella astra Zones after Costa et al. (1978), Hardenbohl & Berggren (1978) and King (1981).

BASE OF THE LATE EOCENE:

w* At the base of P12, Curry et al. (1978).

x* At the base of NP17, Costa & Muller (1978).

y* Near the top of NP17, Haq & Lohmann (1978). At the base of NP18, Hardenbohl & Berggren (1978).

BASE OF THE OLIGOCENE:

z* Base of NP21, Costa & Muller (1978), Curry et al. (1978) and Haq & Lohmann (1978). Base of P. micra Zone, Hardenbohl & Berggren (1978).

BOUNDARIES OF LITHOSTRATIGRAPHIC UNITS:

r* Base of the Thanet Beds after Curry et al. 1978.

s* Base of the London Clay in the London Basin is within the A. hyperacanthum Zone, after Knox & Harland 1979.

t* Base of the London Clay after Costa & Muller (1978); King (1981) suggests the oldest London Clay at Alum Bay is Division A3, equivalent to the W. meckelfeldensis Zone of Costa & Downie 1976.

u* Costa & Muller (1978) place the top of the London Clay in southern England at the base of NP13 (D. lodoensis). King (1981) places it within NP12 but at a higher level in the London Basin than in the Isle of Wight.

Figure 1.2

SERIES		PLANKTONIC FORAMINIFERA A	B (P)	CALCAREOUS NANNOFOSSILS C (NP)	DINO — FLAGELLATE CYSTS D	ISLE OF WIGHT (WEST)	LONDON BASIN
OLIGOCENE	MID.	G. opima opima	21	24			
				23 S. predistentus	W. gochtii	HAMSTEAD BEDS	
		G. amliapertura	20				
	EARLY	C. chipolensis	19	22 H. reticulata	?	BEMBRIDGE BEDS — MIDDLE HEADON BEDS	
		P. micra	18				
	z*			21 E? subdisticha			
			17				
EOCENE	LATE	T. cerroazulensis sl.	16	20 S. pseudoradians		LR. HEADON BEDS	
				19 I. recurvus			
		G. semiinvoluta	15	18 C. oamaruensis	R. perforatum		
	y*						
		T. rohri	14	17 D. saipanensis		BARTON BEDS	
	x*						
		O. beckmanni	13	16 D. tani nodifer	R. draco		
		M. lehneri	12				
	w*						
	MIDDLE	G. subconglobata	11	15 C. alatus	K. coleothrypta	BRACKLE - SHAM BEDS	BAGSHOT BEDS
		H. aragonensis	10	14 D. sublodoensis			
	EARLY	A. pentacamerata	9	13 D. lodoensis			
		M. aragonensis	8				
			e*				u*
		M. formosa formosa	7	12 M. tribrachiatus	W. varielongituda		
		d*					
		M. subbotinae	6	11 D. binodosus	W. similis	LONDON CLAY	LONDON CLAY
		c*					
		M. edgari		10 M. contortus	W. meckelfeldensis		
	v*				W. astra		
		b*				t*	
PALAEOCENE	LATE	M. valascoensis	5	9 D. multiradiatus	A. hyperacanthum	READING BEDS	s* Oldhaven/ Blackheath Beds Woolwich/ Reading Beds
		a*		a*			
		P. pseudomenardii	4 (part)	8 H. riedeli	D. speciosa		THANET BEDS
				7 D. gemmeus			r*

they contain are also facies controlled and are only suitable for local correlation.

Within the last thirty years however, several different groups of microfossils have been used to establish zonal schemes which facilitate long-distance correlation between Tertiary successions (Curry et al. 1978, p.13-15). The most widely used groups include planktonic foraminiferids (Bolli 1957, 1966, Banner & Blow 1965, 1969, Berggren 1969 and Stainforth et al. 1975), calcareous nannoplankton (Bramlette & Riedal 1954, Bramlette & Sullivan 1961, Hay et al. 1967) and dinoflagellate cysts (Eaton 1971, 1976, Caro 1973, Costa & Downie 1976, Costa et al. 1978, Ioakim 1979). Correlations have been made between these zonal schemes (Martini 1970, Martini & Worsley 1970) and Hardenbohl & Berggren (1978) link them with a numerical ("geochronometric") time-scale. Martini (1971) indicates the relationship between the nannoplankton zones and many standard reference sections. Costa & Müller (1978) correlate dinoflagellate and nannoplankton zones from north-west Europe and the north-east Atlantic and revise the boundaries of several dinoflagellate zones in the Palaeogene deposits of southern England.

Although these zonations have been useful for establishing correlations in Tertiary deposits they do have their limitations; the significant fossils are often absent and several workers disagree on the details of correlation between different zonal schemes. Some of the main controversial levels in the Palaeocene and early Eocene are indicated in Figure 1.2. For this figure correlation between the two planktonic foraminiferid zonations and nannoplankton is taken from Hardenbohl & Berggren (1978) and the relationship between dinoflagellate and nannoplankton zonations and the lithostratigraphic units of the London and Hampshire Basins follows Costa & Müller (1978). It cannot be assumed however, that all of these zones have been recognised in sections from southern England and no direct correlation is implied between the planktonic foraminiferid zones and either the dinoflagellate zones or lithostratigraphic units.

Most lithological units of the London and Hampshire Basins were named during the late 19th and early 20th

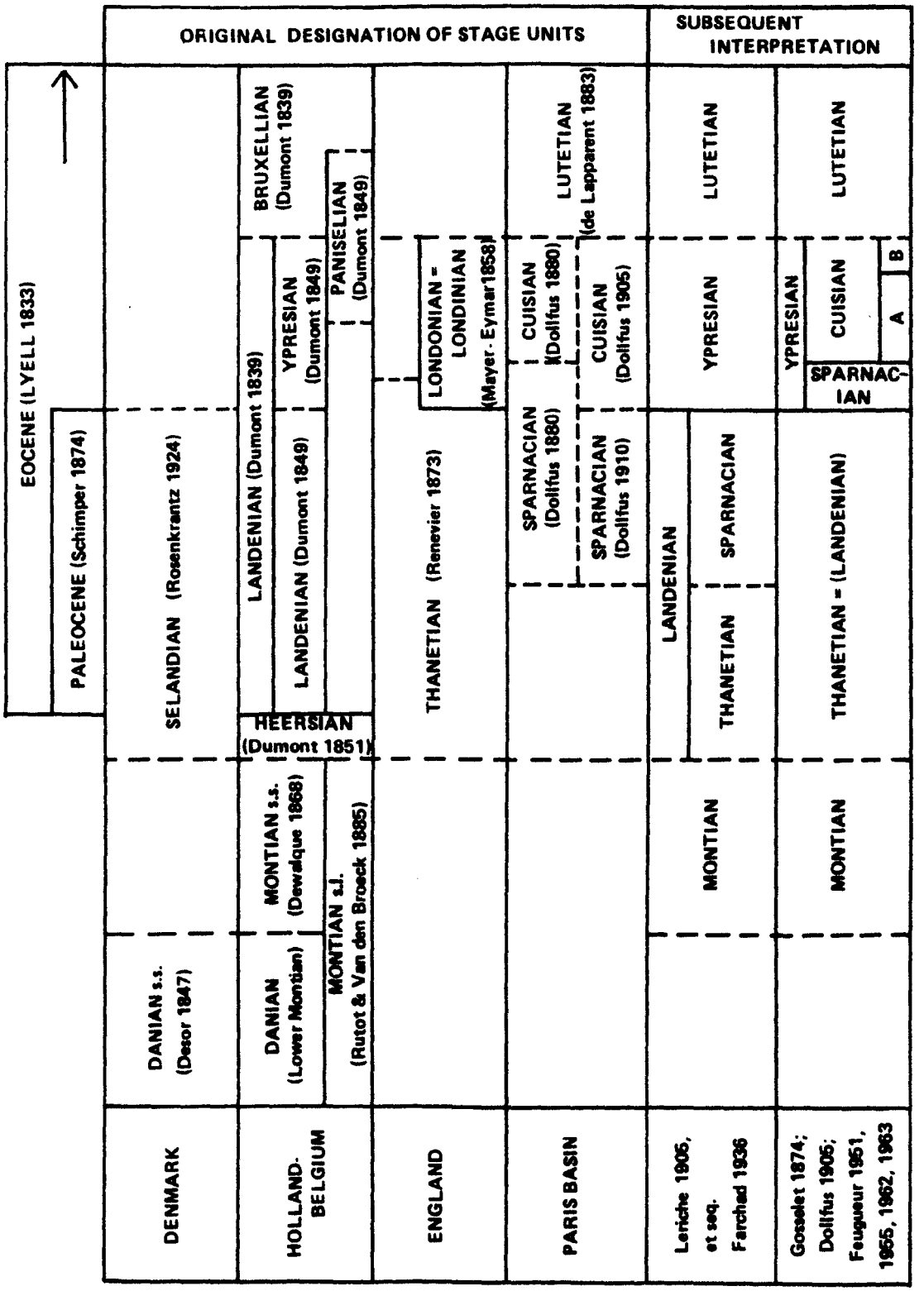


Figure 1.3 Chronostratigraphical concepts of the Palaeocene and lower - middle Eocene (after Berggren 1971).

centuries (Curry 1958). More recently attempts have been made to standardise the nomenclature in accordance with the principles stated in the reports of the International Subcommission on Stratigraphic Classification (Hedberg 1972a, b) but the lithostratigraphical units have not always been adequately defined and ambiguities have arisen (Stinton 1975, Cooper 1976, Curry et al. 1978, King 1981). The traditional nomenclature has therefore been retained in this study.

The oldest Tertiary deposits present in southern England are the Thanet Beds (Fig.1.2) which occur only in the London Basin. They are overlain by the Woolwich and Reading Beds, some part of which is present in both the London and Hampshire Basins. The succeeding Blackheath and Oldhaven Beds have a very limited distribution and are restricted to an area east of Guildford. The London Clay is widespread and occurs in both basins, overlain by only the Bagshot Beds (early-middle Eocene) in the London area but in Hampshire and the Isle of Wight it is succeeded by a more complete Palaeogene succession comprising the Bracklesham, Barton, Headon and Osborne Beds, the Bembridge Marls and Hamstead Beds (early Eocene-middle Oligocene).

Figure 1.3 (after Berggren 1971) shows both the original designation of early Tertiary stages and later modifications now in general use in north-west Europe. Most of these names originated on the continent and are consequently difficult to apply to the British succession. After reviewing the palaeontological and lithological evidence from British and European sequences Curry (1967) concludes that, in the early Palaeogene, the Thanet Beds are Thanetian, the Woolwich and Reading Beds and Blackheath and Oldhaven Beds are Sparnacian, and the London Clay and part of the Bagshot Beds are Ypresian. French workers have generally interpreted the British succession differently and also include the London Clay in the Sparnacian (Feugueur 1963, Blondeau, Cavalier, Feugueur & Pomerol 1965).

In spite of progress in correlation there is no international agreement on the position of the Palaeocene-Eocene boundary. Curry et al. (1978) summarise the arguments in favour of several alternatives. Pomerol (1973, 1975, 1977) and Plaziat (1975) suggest it should be placed at a marked

change in mammal faunas which approximately corresponds with the base of the planktonic Foraminiferid Zone P5 (see Fig. 1.2). This occurs towards the base of the Woolwich and Reading Beds. A few people (Hay & Mohler 1967 and Kapellos & Schaub 1975) place the top of the Palaeocene at the top of the Ilerdian but this stage is difficult to recognise in north-west Europe and its top only roughly corresponds to the Foraminiferid Zone P7. The original definition of the Palaeocene (Schimper 1874) included a series of beds now regarded as Thanetian, Sparnacian and Cuisian although Schimper placed the London Clay in the Eocene. In 1885 Von Koenen redefined the Palaeocene to correspond to the Montian, Thanetian and Sparnacian stages with the base of the Eocene at the base of the Ypresian. Most American and some European workers (Bolli 1957a, Berggren 1965, Stainforth et al. 1975, Martini 1971, Costa et al. 1978 and Curry et al. 1978) agree with Von Koenen and favour a boundary at the base of the London Clay, near the base of the Foraminiferid Zone P6b (roughly equivalent to the base of the Nannoplankton Zone NP10 and of the Wetzeliella astra Dinoflagellate Zone). But Eames (in Davies 1975) points out that the lowest part of the London Clay belongs to the Foraminiferid Zone P6a and must therefore be referred to the Palaeocene. This view is also supported by the more recent work of Knox & Harland (1979) and King (1981).

1.3 THE PALAEOCENE AND EARLY EOCENE DEPOSITS OF THE LONDON BASIN AND THEIR ENVIRONMENT OF DEPOSITION.

As described above (Section 1.1) the London Basin contains the oldest Tertiary strata present in Britain, the Thanet Beds, the Woolwich and Reading Beds, the Blackheath and Oldhaven Beds and London Clay (Fig. 1.2).

Since these deposits were first studied in the early part of the 19th century their lithology, distribution, faunas and floras have been described in some detail (see for example Boswell 1915; Chandler 1961, 1962, 1964; Cooper 1976; Curry 1958, 1965; Gamble 1968; Gurr 1963; Hawkins 1946, 1955; Hester 1965; King 1981; Prestwich 1850, 1852, 1854;

Reid & Chandler 1933; Stamp 1921; Ward 1978; Whitaker 1866, 1872, 1889; Wrigley 1949).

The Thanet Beds.

The Thanet Beds overlie Senonian Chalk with a marked unconformity. Curry (1965, p.155) estimates that a period of about 15 million years must have elapsed between the deposition of the highest Chalk at Ramsgate and deposition of the Bullhead Bed, (the basal Thanet Beds) and Wrigley (1949) suggests that at least 150m of Maastrichtian Chalk must have been removed by erosion.

The Thanet Beds outcrop only in the eastern part of the London Basin, in an area extending from the Kent Coast near Ramsgate westwards as far as Epsom in Surrey and northwards to the vicinity of Ipswich in Suffolk and Gestingthorpe in northern Essex. This northern limit is poorly defined since the Thanet Beds are lithologically very similar to the overlying Woolwich Bottom Bed and are not easy to distinguish in records of boreholes (Boswell 1915). From their maximum thickness of about 35m in the east the Thanet Beds thin westwards to about 6 metres in the London area and eventually die out near Epsom.

The basal unit, the Bullhead Bed is composed of unworn, green-coated flints in a matrix of dark green glauconitic, silty sand and clay; it is comparatively thin (up to 1.5m) but is widespread, extending beneath the entire outcrop of the remaining Thanet Beds. These consist of glauconitic fine sands, silts and silty clays. Whitaker (1872) recognised three divisions in the east which thin westwards and, near Rochester, are replaced by a single sand unit.

Wrigley (1949) suggests that the Thanet Beds were deposited in shallow marine conditions adjacent to a land area with low relief; the presence of unbroken bivalves which are not waterworn implies a low energy environment and the fishes (according to Leriche) are decidedly littoral. Haynes (1958) points to the unworn flints in the Bullhead Bed as evidence of rapid inundation. This was followed by the establishment of marine conditions with a period of maximum marine transgression (represented by the Upper

Pegwell Marls, see p.41 below) during which subsidence outpaced deposition. The faunas are characteristic of outer shelf (outer neritic) environments and may indicate depths greater than 50m. The upper part of the Thanet Beds (the Reculver Silts) represent deposition in very shallow water during the regressive phase.

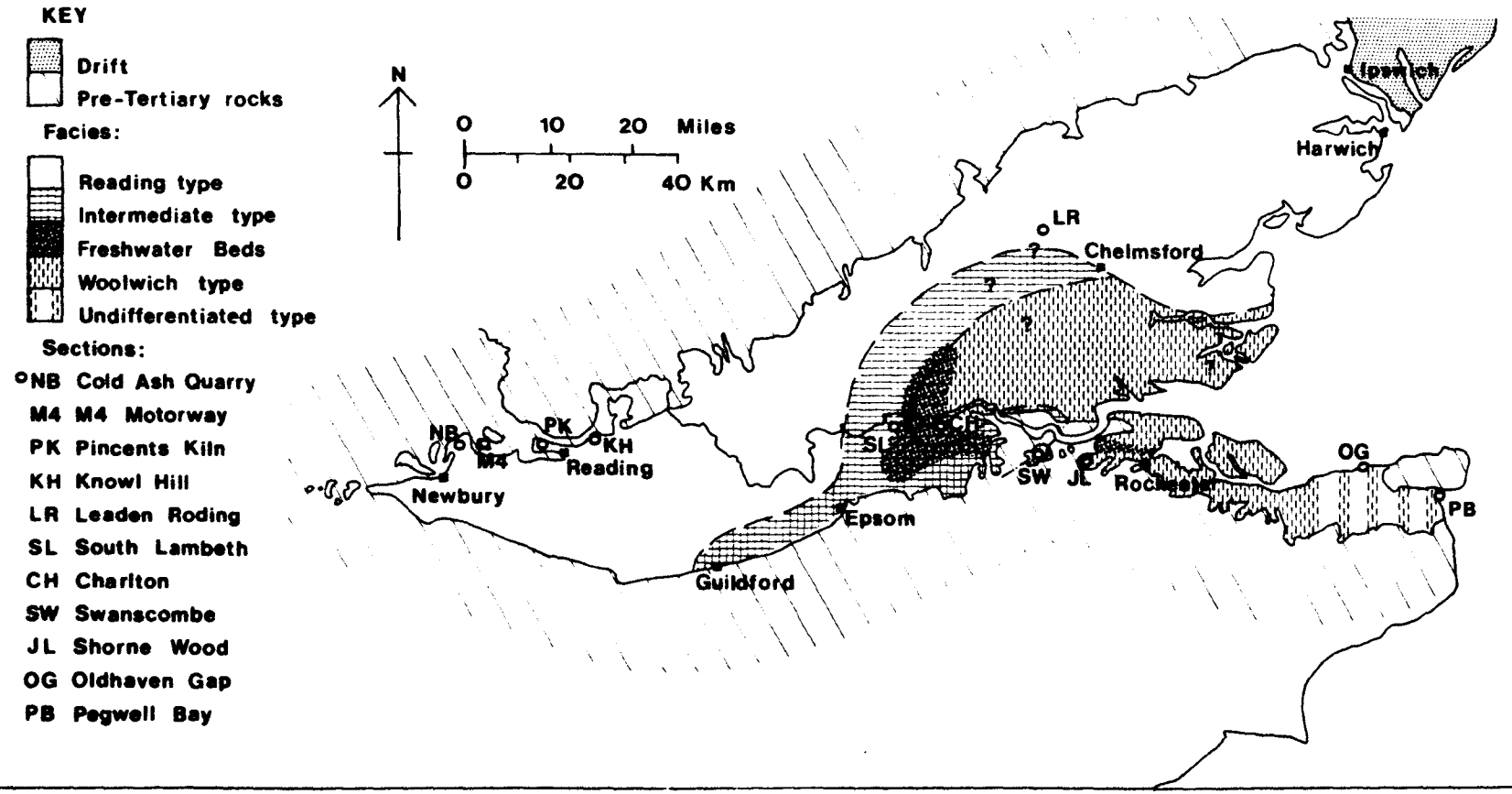
There is no general agreement about the climatic regime which prevailed during the deposition of the Thanet Beds. Haynes (1958) considers that the presence of the cool-water genera Astarte and Cyprina indicates a cool sea in a temperate or mediterranean climate and the absence of larger and porcellanous foraminiferids and low average size of the fauna is taken as further evidence of cool conditions. Wrigley however (1949, p.45) favours a sub-tropical rather than boreal climate and points out that although the molluscs Astarte, Aporrhais and Cyprina are accepted as indicative of a boreal sea, these genera do occur in the London Clay at Sheppey in sediments which also contain a "rich and varied tropical flora". He cites other genera which also occur in the French Thanetian, including fish, as indicative of warm water.

The Woolwich and Reading Beds.

The basal unit of the Woolwich and Reading Beds, the Bottom Bed, marks a major marine transgression which extended across the London Basin, south through the Hampshire Basin and into the English Channel (Curry et al. 1978). The Bottom Bed overlies Thanet Beds (where these are present) but in the west of the London Basin oversteps them to rest directly on the Chalk. Both the Thanet Beds and the Chalk commonly contain borings filled with glauconitic sand brought down from above. The bored surface is interpreted (Hester 1965) as an inshore, intertidal wave-cut platform which was swept clear of deposits before the deposition of the Bottom Bed.

In the London Basin the Woolwich and Reading Beds as a whole are thickest in the Chertsey area (c.25-35m) with a sub-basin centred on Newbury where c.25m are

DISTRIBUTION OF DIFFERENT FACIES WITHIN THE WOOLWICH AND READING BEDS IN THE LONDON BASIN (AFTER HESTER 1965) WITH LOCATION OF SECTIONS STUDIED.



recorded (Hester 1965). Deposits are thinner in the east where they are overlain by the Blackheath and Oldhaven Beds.

The basal part of the Bottom Bed comprises a pebble bed of flints in a matrix of glauconitic sand and contains abundant oysters, Ostrea bellovacina, at some horizons, particularly in the west of the London Basin. Prestwich (1854) reported them as far west as Newbury and they were seen in this area during excavations for the construction of the M4 motorway (see p.61 below). The pebble bed is poorly developed in north-west Kent and eastern Essex and in these areas the Bottom Bed may be difficult to separate from the underlying Thanet Beds. The rest of the Bottom Bed, particularly towards the east, is composed of marine sands and silts, usually very glauconitic. In the London area, the marine deposits are sometimes overlain by mottled clays of fluvial origin. Locally these show evidence of emergence in the upper part (see discussion Chapter 5.3). At the extreme east of the basin, (e.g. at Oldhaven Gap) the Bottom Bed is the only representative of the Woolwich and Reading Beds; if higher members were deposited they were removed by erosion before the deposition of the Oldhaven Beds.

In the Reading and Newbury area the Bottom Bed is more complex and of irregular thickness due to erosion before the deposition of the overlying strata (Hawkins 1955, Hester 1965). Hawkins (1946, p.170, fig.26) describes an exposure at Theale near Reading where the Bottom Bed comprises a basal, glauconitic, pebble bed (0.2m) overlain by a series of glauconitic sands and loams (c.1.35m), with occasional flint pebbles. These are followed by pale grey silty clays (c.1.2m), within which there is a layer (c.10cm) of "peat of matted leaves". The clays are succeeded by thick, cross-bedded sands, typical of the Reading facies of the Woolwich and Reading Beds (see below). The Bottom Bed at Theale (as defined by Hawkins, 1946) compares well with the Pincents Kiln section, in which the clays are full of poorly preserved leaves and leaf impressions. There is no massive leaf accumulation comparable to Hawkins's "peat" however.

In the later publication (1955, p.415), Hawkins mentions difficulty of recognising the top of the Bottom Bed. He

comments that "if it (the Bottom Bed) is to be considered as a marine facies contrasting with the normal estuarine development, and if glauconite is taken as an index of marine conditions, the thickness of the bed as thus determined shows an extraordinary variation". Using these criteria only the glauconitic sands and loams at Theale and Pincents Kiln should be included in the Bottom Bed. Samples of the clays from Pincents Kiln that I have examined do contain rare dinoflagellate cysts however, evidence of some marine influence during deposition. This is a problem which can only be resolved by more study of the Reading Beds.

Where the higher parts of the Woolwich and Reading Beds are present, west of Kent, they are a complex series of sands and clays which show three distinct facies (Fig. 1.4 and Fig.1.5 after Hester (1965) and King (1981)).

1. The Reading Beds. These occur in the west and north of the London Basin, extend southwards into the Hampshire Basin and are also known from the English Channel south of the Isle of Wight (Curry 1962). They comprise thick sequences of sands and mottled clays which are laterally impersistent. Usually the sands underlie the mottled clays but they frequently interdigitate and either may be absent. It is rare however for the sands to overly the mottled clay.

The sands are often orange, yellow, red or white in colour and show large and small scale cross-bedding. They occasionally contain pebbles, clay flakes and clay lenses which may contain leaves, fruits and seeds (Collinson & Crane, 1978). In the west of the London Basin, Hawkins (1955, p.416) reports a lignite seam from these sands in a borehole (No.1) in the Enborne Valley, "resting on a bed of gannister-like sand permeated by innumerable branching tubes of pyrite containing carbonaceous matter that can hardly have been other than the remains of rootlets". He suggests this is a continuation of a seam reported c.6.5km (3½ miles) further south at Ewhurst by Prestwich (1854, p.96-97). The Reading Leaf Bed of Newton (in Blake 1903) was recorded about 3.6m above the base of the Reading Beds near Reading.

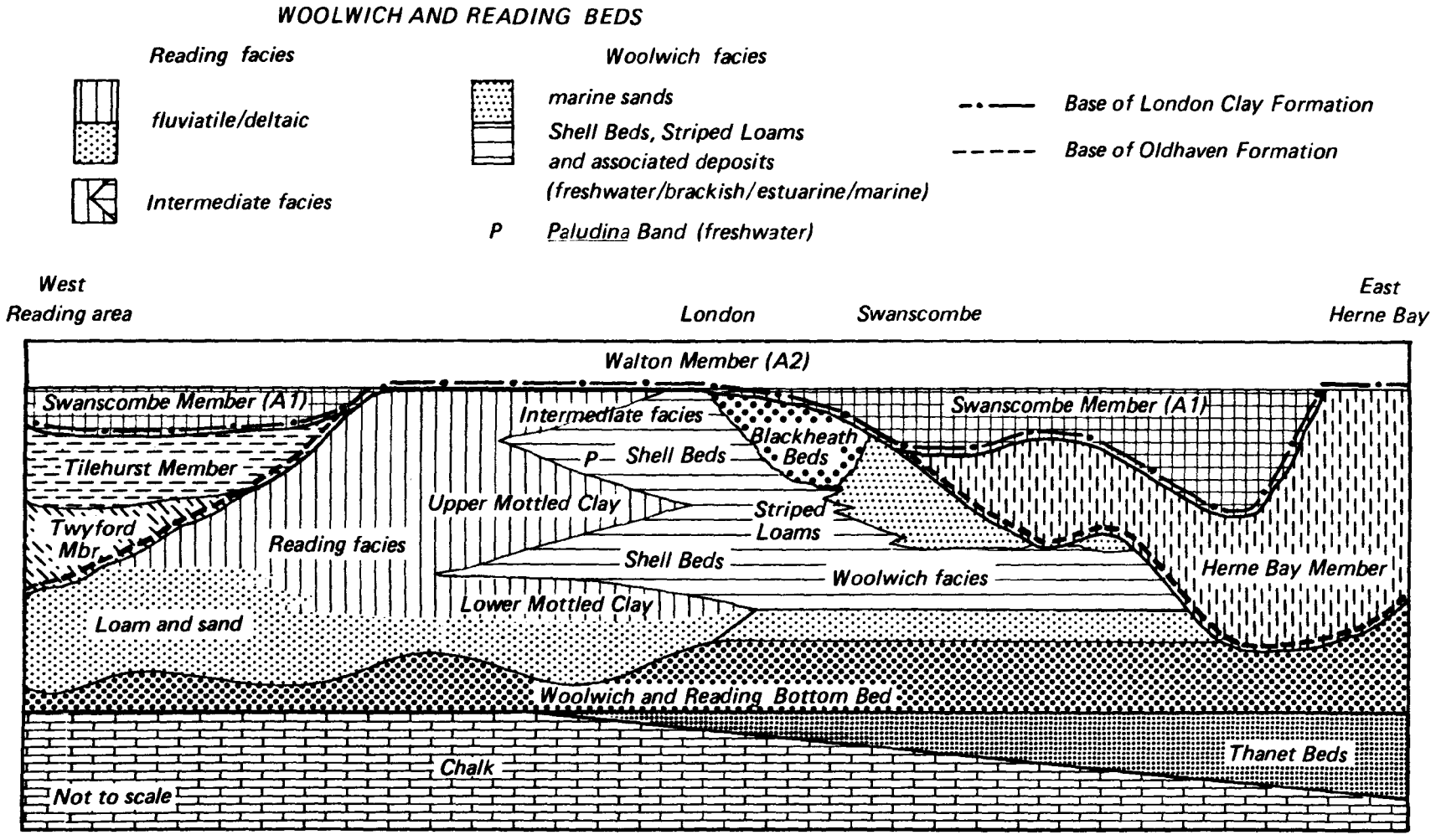


Figure 1.5 Diagrammatic section across the London Basin showing facies within the Woolwich and Reading Beds (after Hester 1965) and members of the Oldhaven and basal London Clay Formations (after King 1981)

The mottled clays are very varied, ranging from white or pale green, to red, blue-grey, or maroon and show evidence of sun-cracks in places (Hawkins 1946). In the Hampshire Basin, in Sussex and coastal areas of East Anglia mottled clay predominates and commonly rests directly on the Bottom Bed (Hester 1965).

Hawkins suggests the lower part of the sequence, in the Reading area (the Bottom Bed sensu Hawkins 1946), represents marine deposition of sands and silts, followed by the development of sand-banks and mud-flats with a series of small islands separated by tidal creeks, at the seaward end of a delta. Vegetation covered the islands and led to the development of "lignitic peat" while leaves falling into stagnant pools produced leaf-beds in pipe-clay (1946, p.169). These beds have little lateral or vertical continuity since islands were gradually submerged and new channels and new islands formed. The Bottom Bed deposits were then covered by the main part of the Reading Beds which were deposited at the landward end of the delta (Hawkins 1946, p.170).

The sands and mottled clays of the Reading Beds are now generally accepted as fluvial deposits (Hester 1965, Curry 1965), possibly part of a braided river system (Collinson & Crane 1978).

2. The Woolwich Beds. These occur above the Bottom Bed in the central part of the London Basin (see Fig.1.4 and Fig. 1.5), at Newhaven on the south coast, in the Dieppe area of France, and have been recorded in the eastern English Channel (Fig. 1.1) (Auffret & Gruas-Cavagnetto 1975, Curry & Smith 1975).

The most characteristic unit is the Woolwich Shell Bed, a series of dark grey clays and yellow sands with abundant molluscs, particularly Corbicula, Brotia and Tympanotonous which indicate brackish-water conditions of deposition. Evidence of more marine conditions of deposition is found in most sequences where thin beds of oysters, Ostrea spp. occur at the base of, or within, the Shell Beds. At Shorne Wood, Swanscombe and in the Crystal Palace Borehole (Rept. Inst. Geol. Sci., No.77/10, 1978, p.9), these directly overly lignitic horizons and indicate a marine incursion following

a period of freshwater deposition. Lignitic horizons occur only locally. Chandler (1923) described a lignite seam 15-75cm thick at the base of the Shell Beds at Shorne Wood, Kent. Elsewhere transported lignitic debris is common, as in the sand immediately below the Shell Beds at Swanscombe (Brown & Priest 1924, Curry 1961, pers. observation). In the area around London an Upper Shell Bed can occasionally be distinguished, separated from the Lower Shell Bed by mottled clays. In a very limited area (see Fig. 1.4) a thin (20cm), grey, argillaceous limestone, the Paludina Band, has been reported within the Upper Shell Bed (Prestwich 1854, Rickman 1861, Dewey & Bromehead 1921, Berry & Cooper 1977). It contains the fresh-water fossils Unio, Viviparus, Planorbis and Hydrobia. Curry (1962) also reports a fresh-water marl within the Shell Beds at Swanscombe.

Above the Shell Beds in some sections (e.g. Charlton) is a series of well-stratified yellow sands and loams with thin laminae of clay known as the Striped Loams (Bromehead in Dewey et al. 1924). At some localities they contain plant remains, particularly in the Lewisham area, where, at Loam Pit Hill, they were reported to contain "a large number of leaves" and were named the Plant Bed by Lavis (1876). They are also known as the Leaf Bed of Lewisham (Pitcher et al. 1967).

3. Intermediate Facies. In the central part of the London Basin, between the Reading Beds and the Woolwich Beds, is an intermediate facies in which wedges of mottled clays and cross-bedded sands typical of the Reading Beds interdigitate with typical Shell Beds (Fig. 1.4, and 1.5). The most westerly occurrence of the Shell Beds, near Guildford, occurs within a sequence of typical mottled clays (Curry 1958).

The whole Woolwich Beds complex (facies 2 and 3) seems to have been deposited in a low lying coastal area, probably adjacent to an estuary. Some of the sand bodies may represent beach barriers or bars. The Shell Beds represent fresh to brackish-water lagoons with adjacent mud flats, behind which fluviatile deposits, consisting of coarse channel

sands and fine alluvial sediments, were laid down. As in the Reading Beds in the west of the Basin, the mottled clays provide evidence of periodic drying out and the development of mudcracks in the alluvial deposits. Lateral migration of these various environments has produced the complex sequences recorded in the Woolwich Beds (Hester 1965, Curry 1965, Berry pers. comm.).

Blackheath Beds, Oldhaven Beds and London Clay Basement Bed.

The Blackheath and Oldhaven Beds have usually been interpreted as lateral equivalents overlying the Woolwich Beds (Curry 1965), but the relationship between them is not clearly understood. The Blackheath Beds occur in south east London and extend into adjacent parts of Kent and Surrey. They are composed of cross-bedded sands and gravels with abundant, well-rounded flint pebbles and with occasional shell lenses. The faunas they contain are marine, estuarine and fresh-water, and may in part be reworked from the Woolwich Beds. At several localities the Blackheath Beds channel deeply into the Woolwich Beds (e.g. at Charlton) and in outliers near Caterham even cut through them to rest directly on the Chalk. They may represent tidal channel deposits cutting mud flats at the landward end of an estuarine complex (Curry 1965).

Traditionally the Oldhaven Beds are considered to be a sandy facies occurring to the east of the Blackheath Beds and laterally equivalent to them. They comprise current-bedded glauconitic sands with occasional pebble and shell horizons and marine (estuarine) faunas (Curry 1965, p.158). Wrigley (in White 1931) and Curry (1965) suggest that the faunas become less marine towards the west. Recently however, King (1981) has re-examined the Oldhaven Beds and London Clay Basement Bed and has reinterpreted the stratigraphical relationships between them. He sees no evidence of brackish faunas in the Oldhaven Beds sensu stricto and considers that marine faunas not only occur throughout their outcrop but that these beds actually overlie the Blackheath Beds, which contain brackish faunas (Fig. 1.5).

The term 'London Clay Basement Bed' is usually applied to the basal metre or so of the London Clay. It is sandy, glauconitic and contains a shallow marine fauna without any estuarine or fresh-water species (Curry 1965).

King shows that the London Clay Basement Bed is in fact composed of several members which are lithologically and faunally distinct and which are separated by sedimentary discontinuities. He considers most of the Basement Bed in the west of the London Basin, and in the Hampshire Basin, to be laterally equivalent to the Oldhaven Beds.

London Clay and Bagshot Sands.

The London Clay proper is a dark brownish or bluish grey marine clay with varying quantities of silt and fine sand. It extends across both the London and Hampshire Basins, attaining its greatest thickness east of London (155m), and in the south east of the Hampshire Basin (130m), becoming thinner westwards.

Early attempts at correlation between the London Clay of the London and Hampshire Basins (Wrigley 1940, Davis & Elliott 1958) were not entirely successful due to differences in lithology and fauna. In the last decade however, the dinoflagellate zonations of Costa & Downie (1976), Costa et al. (1978) and Eaton (1971, 1976) have enabled correlations to be made within Britain and also between the British and north-west European sections.
Furthermore, the recognition of ash-bearing sediments towards the base of the London Clay in East Anglia (Knox & Ellison 1971, Knox & Harland 1979) has been extremely useful for correlation with Denmark, north Germany and sequences in the North Sea. The ash-series in the North Sea Basin occurs within the Apectodinium hyperacanthum Dinoflagellate Zone of Costa & Downie (1976) (latest Palaeocene). It consists of up to 150 individual ash beds interbedded with marine sediments but is not always complete. In the southern North Sea and in East Anglia the lower part of the ash-series is missing and, locally in the central North Sea, the upper part may be cut out (Knox & Harland 1979). Knox and Harland suggest that the absence of the ash-series from the sequence at Oldhaven Gap implies that

the basal London Clay there is younger than that containing the ash-series in East Anglia. This view is supported by the recognition (Costa et al. 1978) of the younger Wetzeliella astra Zone in the basal London Clay at Oldhaven Gap. Knox & Harland consider that, after a late Palaeocene regression the sea was restricted to the central part of the North Sea Basin. Later, during the deposition of the ash-series a 'London Clay' transgression extended southwards over the southern North Sea, Germany, Netherlands and East Anglia. Only after ash deposition had ceased did the sea transgress the south of England, Belgium and northern France. King (1981) doubts that marine deposition in the late Palaeocene was ever as restricted as Knox & Harland imply.

The London Clay is composed of clays and silty clays through most of the London Basin. Diverse floras, particularly fruits and seeds, have been described from these deposits (Reid & Chandler 1933 and Chandler 1961, 1962, 1964; see Chapter 3). Sandy facies are more common within the London Clay in the west of the London Basin and in the Hampshire Basin. There a series of three to five minor transgressive/regressive cycles has been recognised (King 1981), each marked by a basal pebble horizon or glauconitic sands overlain by a sequence which coarsens upwards from clay at the base to silty sands above. Faunas alter with these changes of facies. A period of maximum transgression is recognised in the middle of the London Clay where lithologies are less sandy and both macro- and microfaunas indicate deep-water (180-360m) conditions of deposition (Curry 1965). Above this level in the western areas the sandy lithologies of the regressive phase of each succeeding cycle become more pronounced until the last cycle is almost entirely sand. Typical London Clay sediments accumulated only in the east of the London Basin at this time. King (1981) suggests that these sequences represent progressive progradation of marginal sandy facies into the basin of deposition. Ultimately, in the overlying Bracklesham Group, extensive fluviatile and intertidal deposits were laid down in the Hampshire Basin. In the major part of the London Basin lithologies are more uniform and fine-grained

and the transgressive/regressive cycles can only be recognised by faunal changes. Eventually, even in the London Basin, typical London Clay deposits were overlain by the laminated and pure sands of the Claygate Beds and Lower Bagshot Beds. The Bagshot Beds of the London Basin are mainly marine sands with subordinate clayey bands and, in part, correlate with the Bracklesham Group of the Hampshire Basin.

Wealden Island.

Prestwich (1852) and subsequent authors, notably Stamp (1921) and Wooldridge (1926) postulate the existence of a "Wealden Island" during the early Tertiary against which the London Clay, Thanet and Woolwich Beds thinned and which provided material (particularly flint pebbles) during the deposition of the Blackheath Beds. Later authors (Wrigley 1940, Davis & Elliott 1958, Curry 1965) consider, however, that the available evidence is inconclusive. King (1981) compares the present Wealden anticlinal structure with the Jurassic-Cretaceous troughs in the southern North Sea which "inverted" to anticlinal structures during mid-Palaeocene, pre-Thanetian times (Heybroek 1975). He believes the isopachytes of the London Clay presented by Wooldrige (1926, Fig. 19), which suggest the presence of a "Wealden Island", are based on incomplete and misleading data. His new data do not provide any reliable evidence of thinning of the London Clay towards the Weald, nor of any change in facies in that direction (King 1981, Fig. 40). The presence of the Wealden Island during the early Tertiary therefore remains unproven.

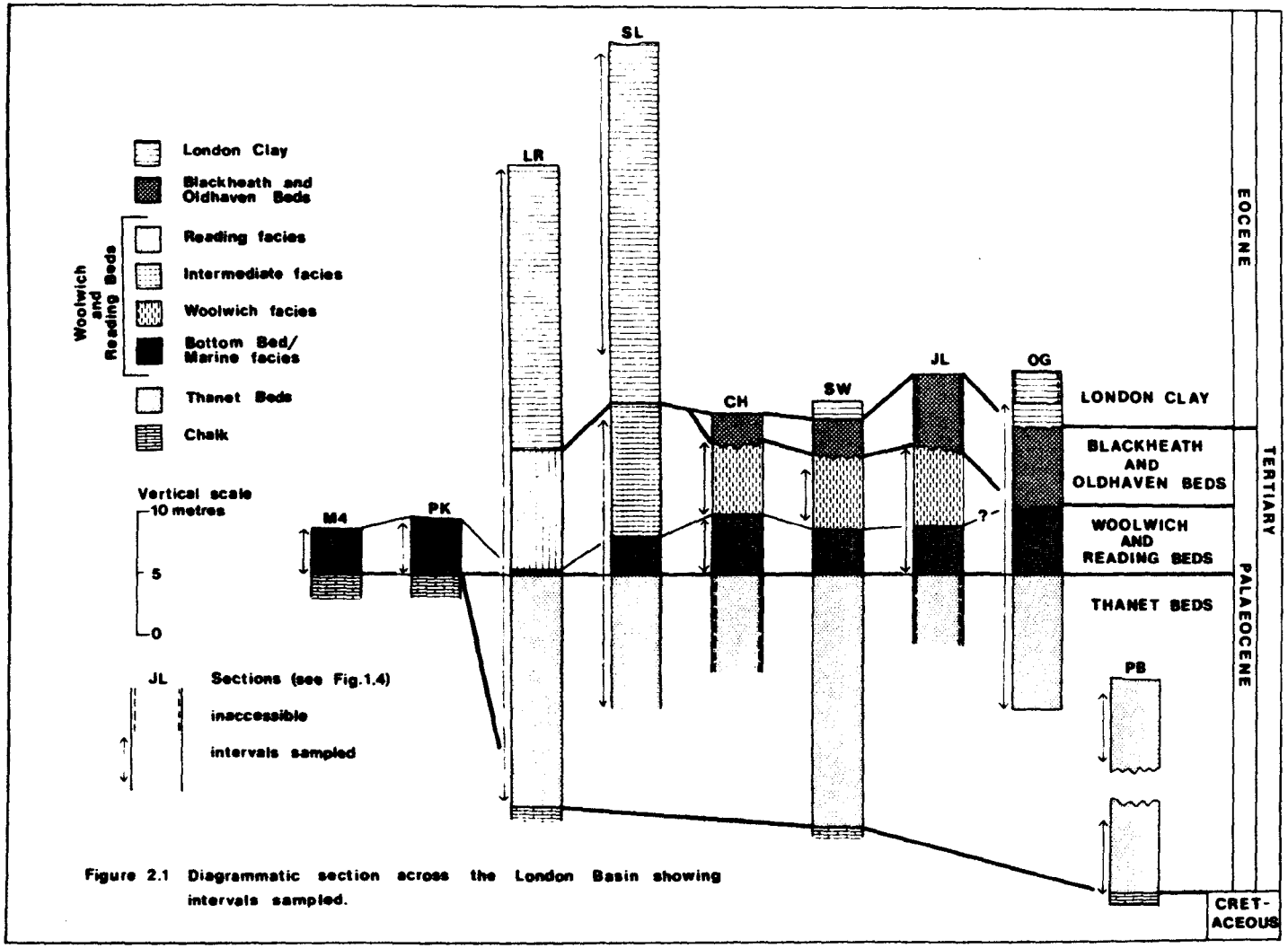


Figure 2.1 Diagrammatic section across the London Basin showing intervals sampled.

CHAPTER 2. SAMPLE COLLECTION AND ANALYSIS.

2.1 SECTIONS STUDIED.

The sections examined lie in a line roughly east to west across the London Basin. They were chosen to include examples of most early Tertiary stratigraphical units from the Thanet Beds to the London Clay including the various facies of the Woolwich and Reading Beds. The position of the main localities studied is shown on Figure 1.4; Figure 2.1 summarises the stratigraphical units present and intervals sampled at each site. Most emphasis has been placed on the Thanet Beds and Woolwich and Reading Beds which were sampled in greater detail than either the Blackheath and Oldhaven Beds or the London Clay. A wider sample interval was also taken through the two borehole sequences (Leaden Roding and South Lambeth Road) than at the actual outcrops.

One section from the Hampshire Basin; Alum Bay (AB), at the western end of the Isle of Wight, was sampled to provide material from the near-shore facies of the London Clay for comparison with the typical London Clay of the London Basin.

The main features of each section are summarised below with brief notes on their palynological content. Details of the microfloras are given in Chapter 5. Lithological summaries are shown on Figures 2.2 to 2.11 and lithological descriptions of each sample collected are given in Tables 1-13 in Appendix 1.

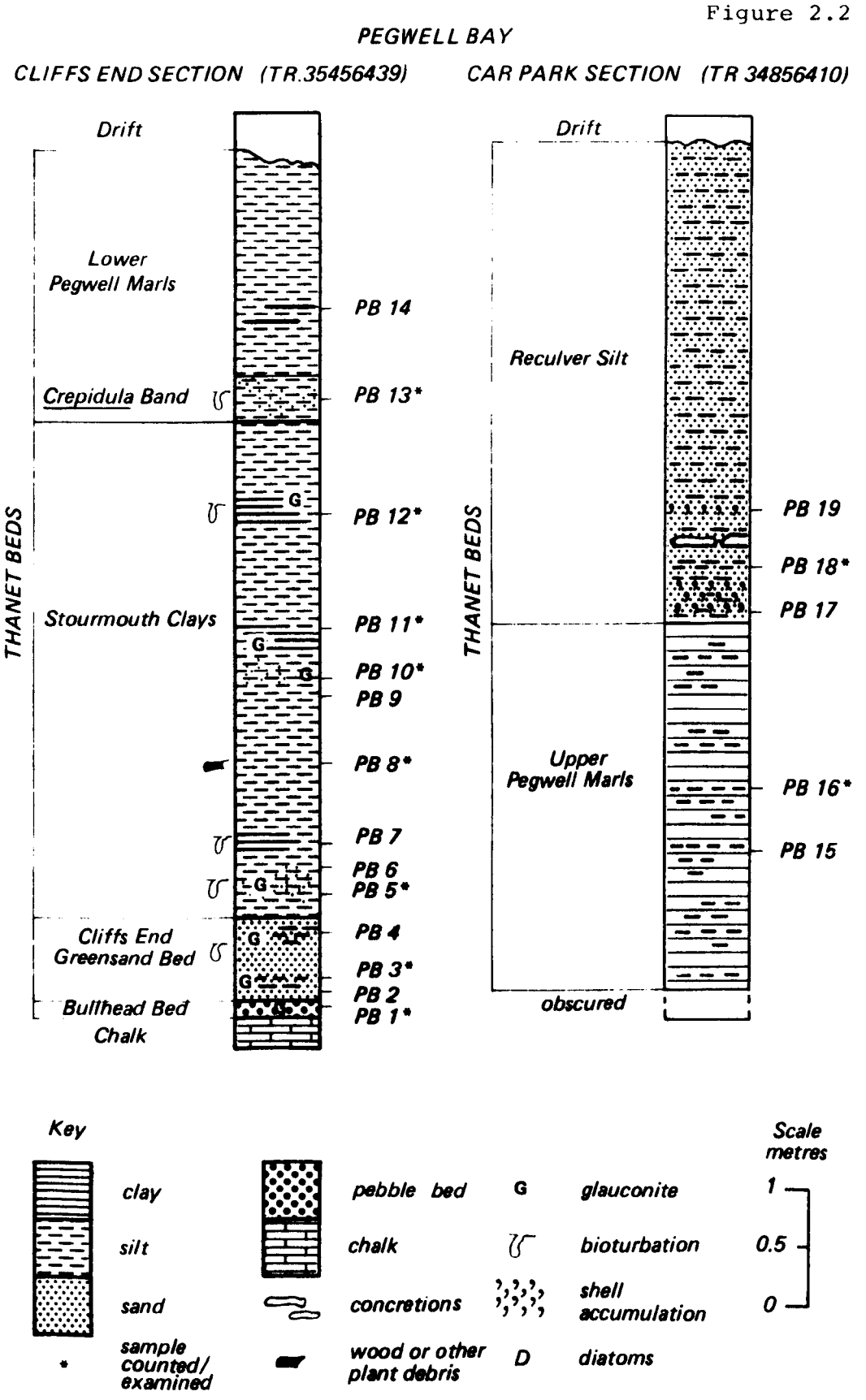
The sections in the London Basin fall naturally into four groups:

GROUP 1; comprising sections in the extreme east of the Basin in which Thanet Beds are well-developed; Pegwell Bay (PB) and Oldhaven Gap (OG).

PEGWELL BAY, Cliffs End Section: TR 35456439 and Car Park Section; TR 34856410 (Appendix 1, Table 1).

The basal part of the Thanet Beds (approx. 15m) is exposed here, c.7.5m in the Cliffs End Section and a higher c.7m behind the Car Park (see Ward 1977 for a detailed map of the localities). Figure 2.2 shows the main lithologies and positions of the samples collected; divisions of the Thanet Beds follow Haynes (1956) and Ward (1977). Both

Figure 2.2


PEGWELL BAY
CLIFFS END SECTION (TR.35456439)
CAR PARK SECTION (TR 34856410)
THANET BEDS
Drift
Lower Pegwell Marls
Crepidula Band
Stourmouth Clays
Cliffs End Greensand Bed
Bullhead Bed
Chalk
PB 14
PB 13*
PB 12*
PB 11*
PB 10*
PB 9
PB 8*
PB 7
PB 6
PB 5*
PB 4
PB 3*
PB 2
PB 1*
Reculver Silt
Upper Pegwell Marls
obscured
PB 19
PB 18*
PB 17
PB 16*
PB 15
Key
clay
silt
sand
sample counted/ examined
pebble bed
chalk
concretions
wood or other plant debris
G
glauconite
bioturbation
shell accumulation
D
diatoms
Scale metres
1
0.5
0

sections are capped by Drift and are generally weathered in the upper part. Nevertheless all beds have yielded palynomorphs, although these are sparse in the coarser Cliffs End Greensand Bed and the Bullhead Bed. The entire sequence falls within the Deflandrea speciosa dinoflagellate Zone of Caro (1973).

Cliffs End Section.

The base of the Thanet Beds is exposed in this section. The Bullhead Bed, a thin conglomerate (0.15m) composed of green-coated flints in a matrix of glauconitic silty sand, overlies a thin tabular flint band at the top of the Chalk. The overlying Cliffs End Greensand Bed (Ward 1977) is also very glauconitic; this silty sand (c.0.75m thick) contains small, scattered flint pebbles and is bioturbated throughout, particularly near the top. Most of the rest of the section comprises the Stourmouth Clays (c.4m), alternating silts and sandy clays, bioturbated at some levels and containing occasional carbonised wood fragments (e.g. PB 8). The Lower Pegwell Marls are the highest Thanet Beds unit present here. They are massive silts and clays with the basal c.0.4m comprising bioturbated silts with numerous small burrows (2-4m) filled with silver sand (the Crepidula Band). Although the upper part of the sequence is heavily leached samples contain moderately rich and diverse microfloras (Chapter 5).

Car Park Section.

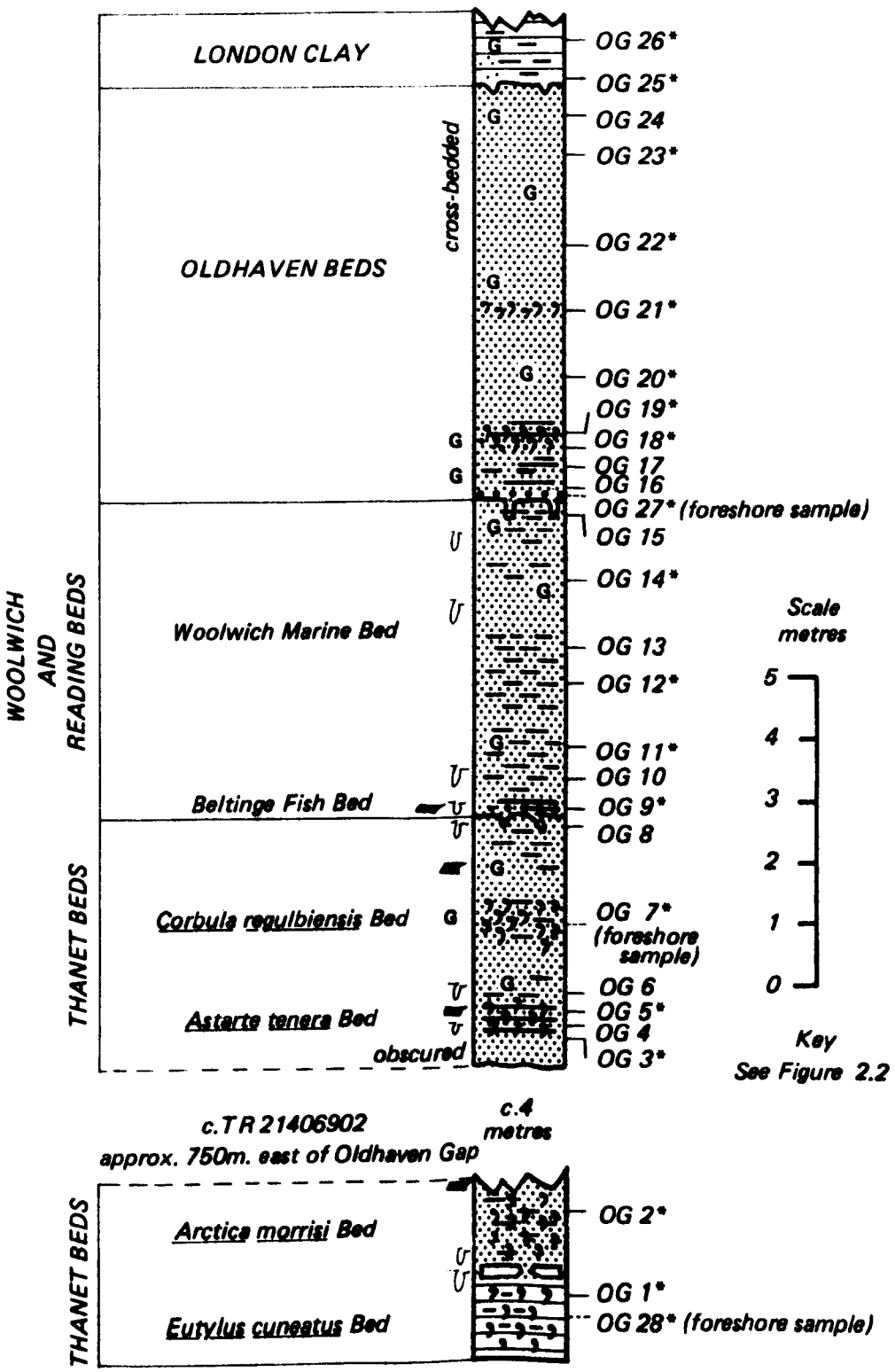
A higher part of the sequence is exposed in the Car Park Section, the Upper Pegwell Marls (silty clays) and the Reculver Silts (sandy silts). The junction is marked by a well-developed shell bed at the base of the Reculver Silts and a second, less persistent, cross-bedded shell bed occurs about 1m above the junction (PB 19). All samples examined contain moderately rich microfloras although palynomorphs are generally pale, probably the result of the deep weathering of the section.

OLDHAVEN GAP: c. TR 20706870 (Table 2 in Appendix 1).

The beds exposed in the cliffs between Herne Bay and Reculver dip gently to the west (at approximately 3^{o}) and

Figure 2.3

OLDHAVEN GAP (TR 20706870) Composite section; see Appendix 1 for details.



include the upper c.17.5m of the Thanet Beds, the Woolwich Bottom Bed (c.5.25m), the Oldhaven Beds (c.7m) and the basal c.3m of the London Clay (Figure 2.3). The main part of the London Clay is no longer exposed in the cliffs which have been levelled and grassed as part of the coastal defences, but it is occasionally exposed on the foreshore at low tide (Ward 1978). Samples were collected from the cliff section east of Herne Bay from c. TR 20586868 to Oldhaven Gap itself (TR 20706870) and also from the headland about 750m east of Oldhaven Gap, at c. TR 21406902.

Thanet Beds.

Only the highest Thanet Beds (Reculver Silts) are present at this locality (c.17.5m). They comprise silty clays and sands, glauconitic in part, with several distinctive shelly horizons (Ward 1978). The lowest one, the Eutylus cuneatus Bed, outcrops in the cliff section near the headland (TR 21406902) below a well-developed concretion band (the Reculver Tabular Band), and is also exposed in the foreshore there. It is a pale grey silty sand (OG 1) more clayey towards the base (OG 28) with abundant bivalves, particularly Arctica morrisi and rarer E. cuneatus. The Arctica morrisi Bed which overlies the concretion band is more sandy and shows evidence of bioturbation. Both of these horizons were sampled (OG 28, OG 1, OG 2) and contain moderately diverse microfloras.

Most of the cliff between the headland and Oldhaven Gap is obscured by landslip and is complicated by small-scale faults (Ward, 1978). East of Oldhaven Gap the upper part of the Thanet Beds is exposed, including the Astarte tenera and Corbula regulbiensis Beds. The former comprises silty sands and clays, glauconitic in part, with a diverse bivalve fauna including A. tenera and Corbula regulbiensis. Ward (1978) reports rare vertebrate remains and abundant rolled wood from this level and considers seeds (particularly of Iodes) and pine cones to be more common here than in any other unit of the Thanet Beds (see Chapter 3). The C. regulbiensis Bed in the cliff face is generally de-calcified. It is a very glauconitic silty sand characterised by large, richly glauconitic clusters or "nests"

(usually silicified) of Corbula regulbiensis. A foreshore sample was processed from this interval (OG 7). Palynomorphs are common in all samples processed from these horizons.

There has been controversy over the position of the junction between the Thanet and Woolwich and Reading Beds at this locality. There is no marked change in lithology and the thick pebble bed recorded at the base of the Woolwich and Reading Beds further west is not present here. Prestwich (1854) originally placed the junction at the base of the C. regulbiensis Bed since he considered that there were faunal changes at that level and this boundary was accepted by others (Whitaker 1866, 1872; Hester 1965). Further work (Gardener 1883, Wrigley 1949) however showed that there are in fact no significant faunal differences between the Corbula regulbiensis and Thanet Beds. Gurr (1963) redefined the junction and placed it at the base of the thin pebble bed about 2m above the C. regulbiensis Bed (now known as the Beltinge Fish Bed) from which he obtained a fish fauna containing several species which appear for the first time in the English Palaeocene, being absent from the C. regulbiensis and Thanet Beds. This junction is now generally accepted (Curry 1965, Ward 1978).

Woolwich and Reading Beds.

The Woolwich and Reading Beds at this locality are entirely marine and consist of a poorly defined basal pebble bed (the Beltinge Fish Bed, c.0.25m thick) and the Woolwich Marine Bed (about 5m thick). The Woolwich Shell Beds were either not deposited in this area or were removed prior to the deposition of the Oldhaven Beds (Hester 1965).

The Beltinge Fish Bed is a glauconitic, silty clay with occasional small, rounded, black flint pebbles, large green-coated sand grains and common pyrite. Wood fragments and rare seeds (Iodes multireticulata and Vitis sp.) have been recorded as well as a vertebrate fauna including sharks teeth and vertebrae (Gurr 1963, Ward 1978). The base is extensively burrowed into the underlying Thanet Beds. Sample OG 9 from this horizon contains a microflora transitional between the Thanet and Woolwich Beds assemblages, possibly the result of bioturbation.

The grey-green, glauconitic silty sands of the Woolwich Marine Bed are bioturbated throughout. Samples from the lower 2-3m (OG 11, OG 12) have yielded moderately rich microfloras but only rare palynomorphs were obtained from the more sandy upper part (OG 14).

Oldhaven Beds

The Oldhaven Beds at this locality have been described as the Herne Bay Member of the Oldhaven Formation (King 1981). They comprise c.7m of glauconitic, cross-bedded sands with occasional clay and shell lenses. In places there is a basal pebble bed composed of rounded, black flint pebbles in a matrix of sand and silty sand. Samples OG 16 and OG 17 were taken from clay lenses within and above the basal pebble bed but did not yield palynomorphs. Several shelly horizons were also sampled but contained only sparse microfloras (OG 18, OG 19) or were barren (OG 21). One foreshore sample (OG 27) from a channel in the base of the Oldhaven Beds was collected by Mr. C. King. This contained a rich microflora with a considerable amount of reworking.

London Clay.

In this section there is no evidence for the presence of the ash-series recorded in the basal London Clay in Essex. This has led Knox and Harland (1979) to suggest that the oldest London Clay at Oldhaven Gap is slightly younger than the basal London Clay in Essex. King (1981) refers it to the Walton Member, Division A2 of the London Clay Formation (Figure 1.5) and believes Division A1 (Swanscombe Member) to be absent. Costa, Denison and Downie (1978) recognise the Wetzeliella astra dinoflagellate Zone at the base of the London Clay at this locality. Two samples were collected from this unit, OG 25 from cross-bedded silty sand and clay about 0.15m above the base and OG 26 from silty clays about 0.7m above the base. The lower sample contains a sparse microflora, the assemblage from OG 26 is richer and more diverse.

GROUP 2; comprising sections in the centre of the London Basin which show well-developed Woolwich facies of the Woolwich and Reading Beds; Charlton (CH), Shorne Wood (JL) and Swanscombe (SW).

CHARLTON SAND PIT, Maryon Park: TQ 419786 (Table 3 in Appendix 1).

The Charlton Sand Pit (formerly known as Gilbert's Pit) was designated a Site of Special Scientific Interest by the Nature Conservancy Council in 1962. The samples I have examined were collected in December 1970 when members of the Tertiary Research Group, under the direction of A.J.Rundle, cleaned and measured a complete sequence from the top of the Thanet Beds, through the Woolwich Bottom Bed, the Woolwich facies of the Woolwich and Reading Beds and the Blackheath Beds. My thanks are due to Dr. Adrian Rundle for the stratigraphical interpretation of this section. Details of previous studies of the biota of this and adjacent localities are given by Rundle (1972).

The succession is summarised in Figure 2.4 which also shows the position of samples collected.

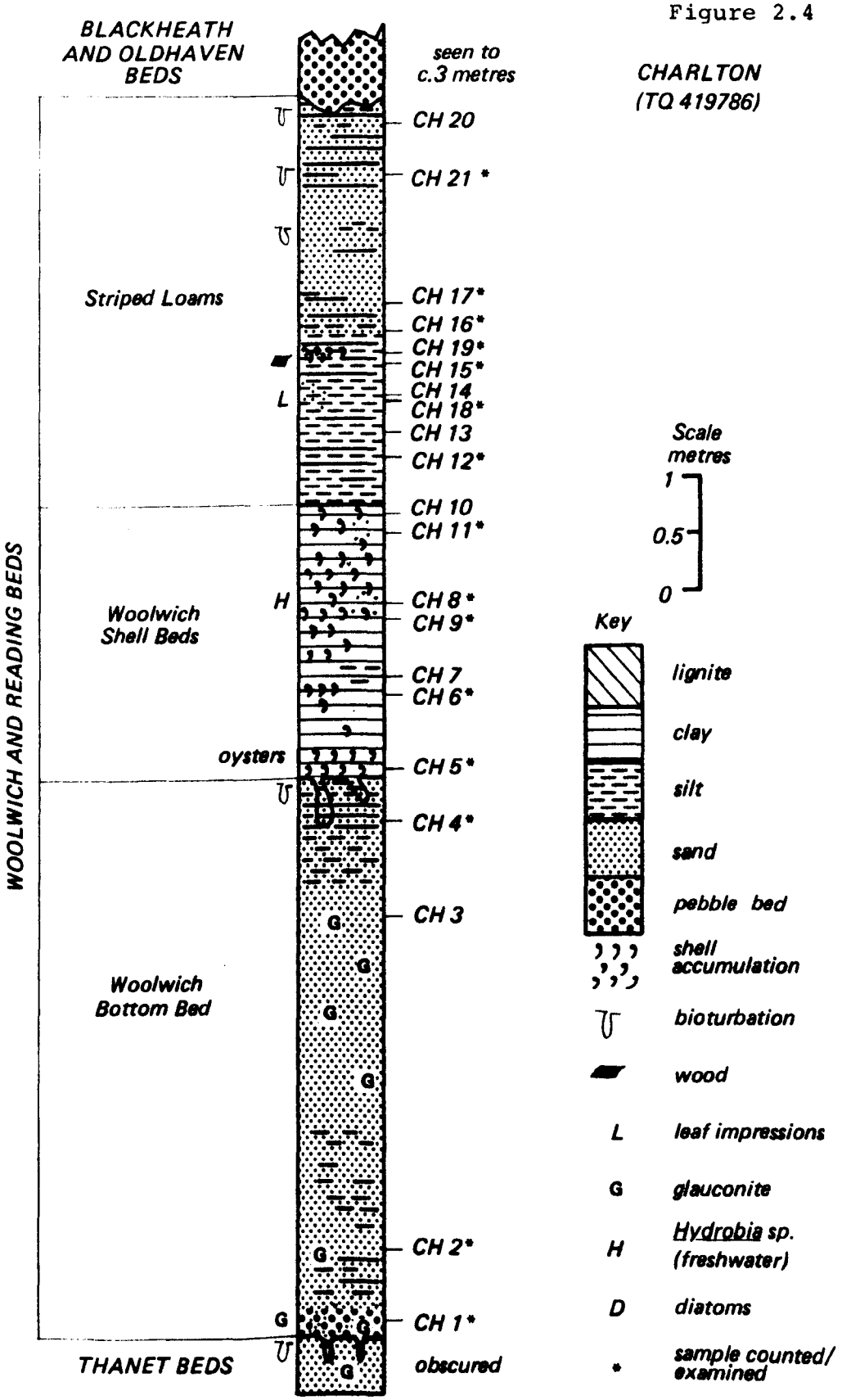
Thanet Beds.

No samples were collected from the Thanet Beds which are fine, whitish, glauconitic, slightly clayey sands. The upper 1.5m are penetrated by burrows with clay infills, extending down from the pebble bed at the base of the Woolwich Beds (Rundle 1972).

Woolwich and Reading Beds.

The Woolwich Bottom Bed consists of a thin basal pebble bed (c.0.25m) succeeded by c.4.6m of mottled sandy silts and silty sands, clayey towards the base and more sandy and glauconitic towards the middle. Sample CH 1 was taken from the glauconitic sandy silt between the small, well-rounded, black flints of the pebble bed. It contains a sparse microflora with several reworked taxa (Chapter 5). This fine-grained material has been carried down into the Thanet Beds by bioturbation. Samples from the higher levels of the Woolwich Bottom Bed were either barren (CH 3, glauconitic sand) or contained only a very sparse microflora (CH 2,

Figure 2.4


BLACKHEATH AND OLDHAVEN BEDS
seen to c.3 metres
CHARLTON (TQ 419786)
CH 20
CH 21 *
Striped Loams
CH 17*
CH 16*
CH 19*
CH 15*
CH 14
CH 18*
CH 13
CH 12*
CH 10
CH 11*
Woolwich Shell Beds
CH 8*
CH 9*
CH 7
CH 6*
oysters
CH 5*
CH 4*
CH 3
Woolwich Bottom Bed
CH 2*
CH 1*
THANET BEDS
obscured
WOOLWICH AND READING BEDS
Scale metres
1
0.5
0
Key
lignite
clay
silt
sand
pebble bed
shell accumulation
bioturbation
wood
L leaf impressions
G glauconite
H Hydrobia sp. (freshwater)
D diatoms
* sample counted/ examined

sand with clay lenses). CH 4 (0.40m below the Shell Beds) contains taxa more characteristic of the Shell Beds, perhaps as a result of bioturbation.

Sediments typical of the Woolwich facies are well developed at this locality. The Shell Beds are c.2.4m thick and comprise grey clays, sandy in places with abundant molluscan shells. Oysters are common at several levels (CH 5, CH 6), closely packed in a dark grey clay matrix; other taxa recorded include abundant bivalves, Corbicula cuneiformis and C. cordata which are present throughout the unit, the gastropods Brotia melanioides and Tympanotonus funatus, common near the top of the unit (CH 9, CH 11, CH 10) and the freshwater gastropod Hydrobia spp. which occurs in isolated lenses (e.g. CH 8) (Rundle 1972). This fauna indicates deposition in brackish, off-shore lagoons (Pitcher et al. 1967) with occasional fresh-water and marine influence. Very rich and diverse microfloras occur throughout although preservation is sometimes poor. Taxa present include dinoflagellate cyst species typical of the Apectodinium hyperacanthum Zone (formerly Wetzeliella hyperacantha) of Costa and Downie (1976).

The highest member of the Woolwich Beds here, the Striped Loams, is also reported from the neighbourhood of Lewisham and Greenwich (Curry 1958) and has sometimes been referred to as the Leaf Bed of Lewisham (Pitcher et al. 1967). At the base the Striped Loams are well-bedded, laminated silts and clays with common sandy layers, a thin shell seam c.1.3m above the base (CH 19) and unidentifiable leaf impressions on the bedding planes at c.0.9m above the base (CH 18). This part of the sequence is probably equivalent to the laminated beds at the top of the Shell Beds at Swanscombe (e.g. SW 38). Above this laminated sequence massive, fine-grained sands and silts predominate, with occassional clay seams (CH 21). Ophimorpha burrows at c.2.5m above the base indicate a marine environment of deposition for that part of the sequence. Microfloras in the lower part of the unit are generally similar to those of the Shell Beds, but the highest sample examined (CH 21) is sparse, lacks Apectodinium spp. and contains more acritarchs and Areoligeraceae.

Blackheath Beds.

The Blackheath Beds channel deeply into the Striped Loams and are about 3m thick at the measured section. Small, well-rounded black pebbles occur in a sparse matrix of silty sand with shelly lenses towards the base. No samples were collected from this unit.

SHORNE WOOD near Cobham, Kent: TQ 67306980 (Table 4 in Appendix 1).

Excavations in this area were described by R.H.Chandler (1923) during the construction of the A2 trunk road. Similar sections were again exposed near Shorne Wood in 1964 when the A2 was widened to motorway standard. At that time the section was sampled by Messrs. S.W. Hester and A.Morter of the Institute of Geological Sciences and some of this material was kindly made available to me for examination in 1970. The exact position of samples above a datum is not recorded in the I.G.S. Sample Register, consequently only approximate positions of samples within each bed can be shown in Figure 2.5. From the thickness of the lowest Shell Bed (Bed 5) and the number of samples collected through it, it appears that this bed at least was sampled continuously (channel samples).

Woolwich and Reading Beds.

A few samples were processed from the Woolwich Bottom Bed but these contained very sparse microfloras.

The Woolwich facies at this locality is particularly interesting since, at the base, it contains a well-developed organic rich horizon, described as a lignite by Chandler (1923). In the original road cutting this varied from 0.15m (6") to 0.6m (2') in thickness and in the later section ranged from 0.6m to 1.2m (1964, I.G.S. Sample Register and Martin 1976). Chandler comments on the lack of woody structure in his samples which was confirmed by microscopical analysis (by Prof. A.C.Seward quoted in Chandler 1923, p.140) "... no trace of any wood and all that I can identify consists of very imperfectly-preserved remains of what I think are leaves. The material seems to consist of a mass

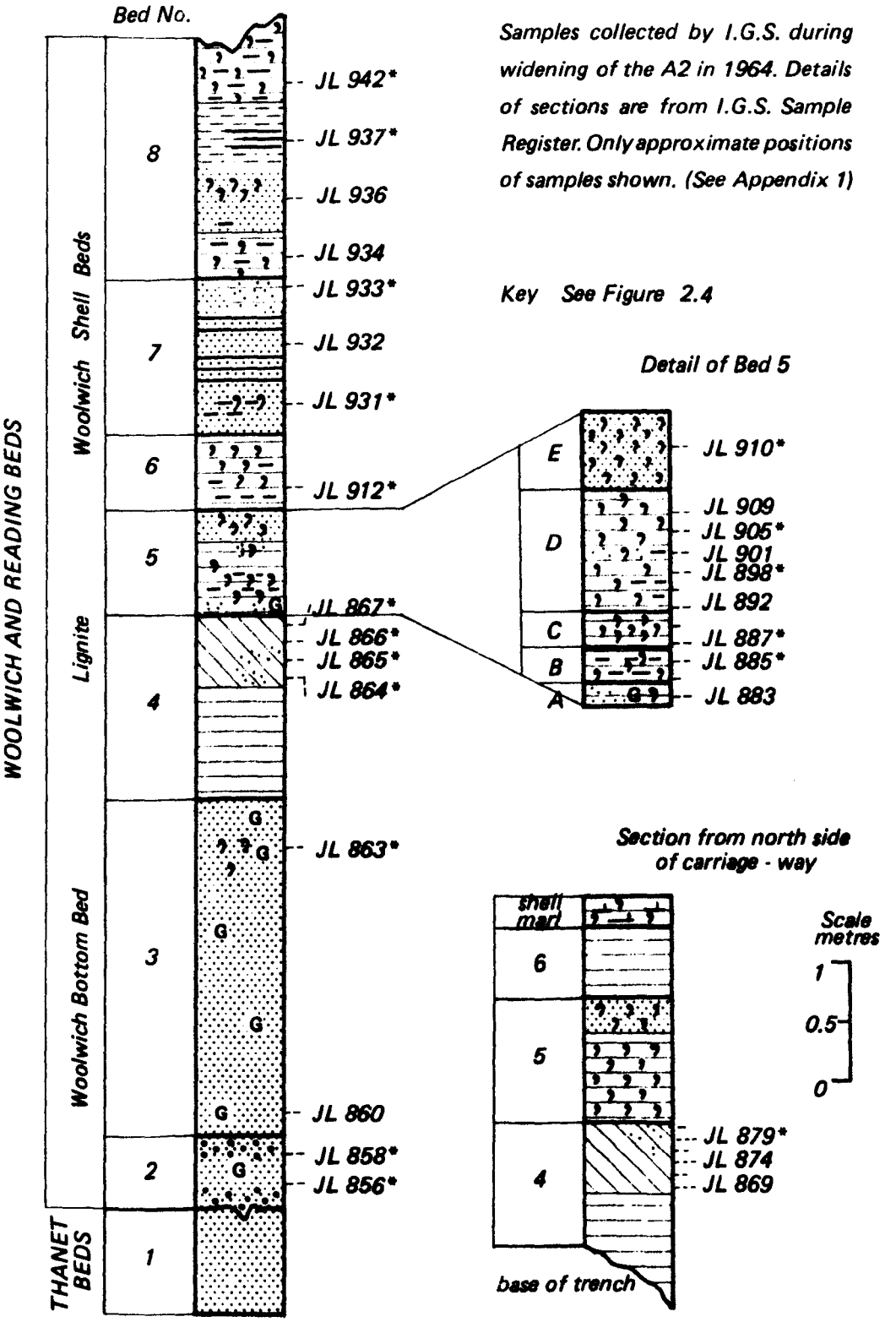
Figure 2.5

Section from south side of carriage - way

SHORNE WOOD (near COBHAM, KENT) TQ 67306980

Samples collected by I.G.S. during widening of the A2 in 1964. Details of sections are from I.G.S. Sample Register. Only approximate positions of samples shown. (See Appendix 1)

Key See Figure 2.4



of decomposed vegetable matter, but what the original plants were it is absolutely impossible to say".

Martin (1976, p.173) considers this deposit is better described as a lake mud. However, although the material I have examined (JL 864 to JL 867) is generally friable and lacks macroscopic wood it is composed almost entirely of carbonaceous material and has none of the clay content one would expect in lake sediments. Samples JL 869 to JL 880, from the north side of the carriage-way, show more structure; woody debris with clear cellular structure is present in JL 871 and JL 880. Some sand lenses are present in several of these lignite samples (JL 864, and JL 865 from the south side of the carriage-way and JL 879 from the north side) and are evidence of some terrigenous influx during formation. Chandler (1923) reported a thin dark grey to black clay c.0.2m (8") thick beneath the lignite; in the later section this was apparently c.0.9m (3') thick (I.G.S. Sample Register). Certainly this deposit is more likely to be lacustrine in origin.

In contrast to the lignite horizon at Swanscombe the thickness and persistence of the lignite seam at this locality suggests it was deposited here (whether in a lake or as a terrestrial deposit) and has not undergone post-depositional transport.

The more friable lignites from the south side of the carriage-way (JL 864-JL 867) contain rich microfloras, as does JL 879. The other more indurated samples from the north side of the carriage-way (except JL 879) only yielded very sparse assemblages including fungal spores or were barren of palynomorphs.

The Shell Beds (particularly Bed 5) have been sampled in detail at this locality. All shelly horizons have yielded rich microfloras, including JL 910, a lightly consolidated, ferruginous, yellowish brown sandstone with abundant bivalve fragments. The least productive samples were the light olive grey sands and clays from Bed 7.

The striped sands and clays (Striped Loams) which occur further to the west were not recorded in the original section and the Blackheath Beds were reported to rest erosively on Bed 9 (unfossiliferous brown clay) nearly cutting into Bed 8 (the upper Woolwich Shell Bed) in places (Chandler

1923, p.139). The highest of the Woolwich Beds recorded in the 1964 cutting however was Bed 8.

SWANSCOMBE, Northfleet Quarry, Kent: TQ 598730 (Table 5 Appendix 1).

The Blue Circle Cement Co. Ltd. have a large quarry (their Northfleet Works) near Swanscombe in Kent which has been in operation for many years for the extraction and processing of the Chalk. The early Tertiary deposits are considered as "overburden" and are gradually being removed, in the process new sections from the Thanet Beds to basal London Clay are exposed. These are adjacent to the sections in road cuttings through Swanscombe Hill described by Stamp & Priest (1921), and Curry (1962). At this locality c.19m of Thanet Beds overlie the Chalk and are succeeded by Woolwich and Reading Beds, Oldhaven Beds and basal London Clay. Since neither the Thanet Beds nor the Woolwich Bottom Bed were well exposed when the section was sampled in 1971 only the Woolwich Shell Beds and underlying carbonaceous sands were collected (Figure 2.6).

Woolwich and Reading Beds.

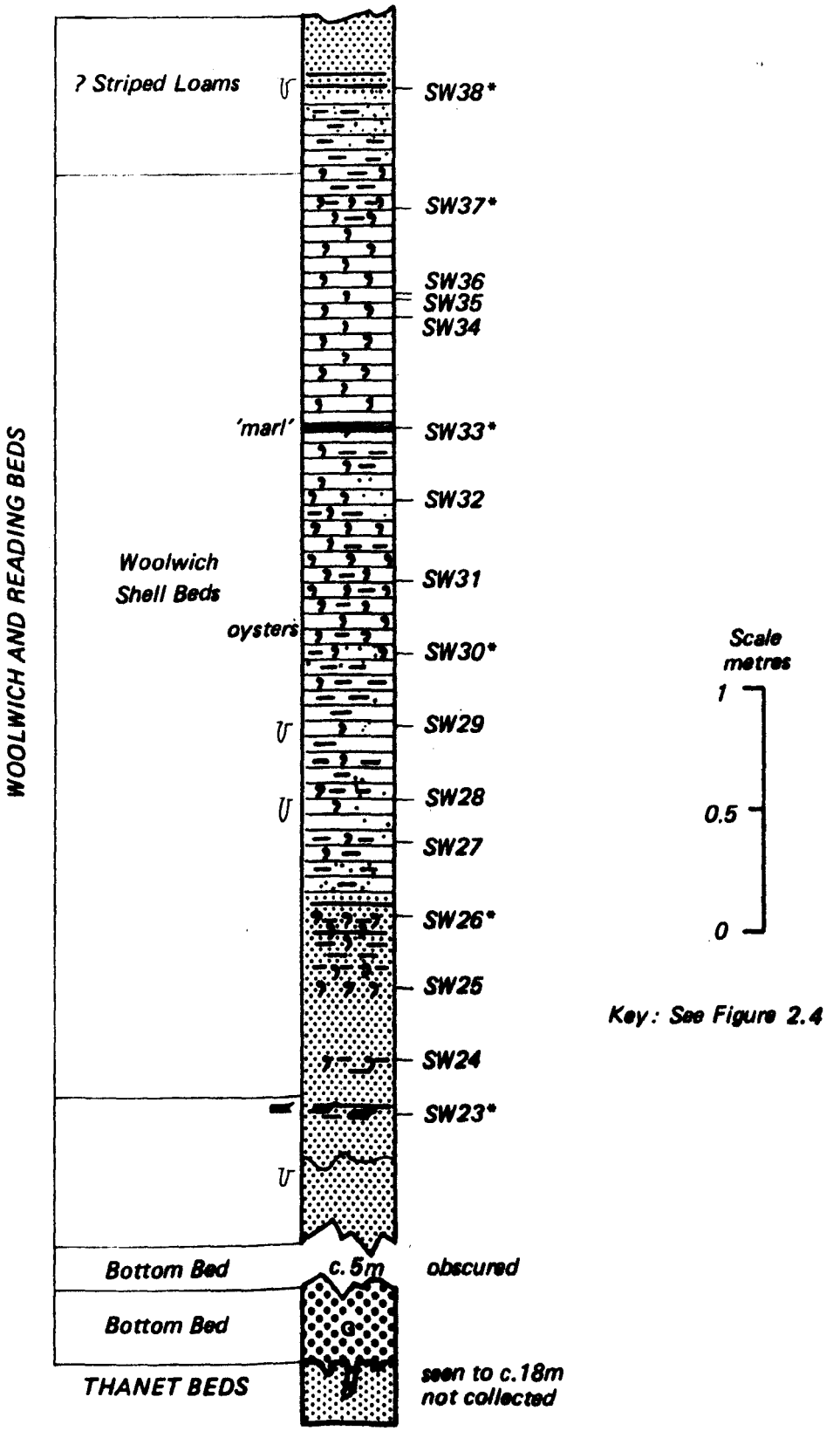
As at Charlton the pebble bed at the base of the Woolwich Bottom Bed is well-developed (c.0.3m thick) and is extensively burrowed into the top of the Thanet Beds. The rest of the Woolwich Bottom Bed (c.4.7m) is very glauconitic at the base, with cross-bedded sands above.

The carbonaceous horizon immediately below the Woolwich Shell Beds is a buff sand full of lignitic debris, mainly in the form of well-worn, charcoalified clasts which appear to have been transported and deposited with the sand some distance from the source. The environment of deposition of this bed thus differs considerably from that of the thick lignitic seam at Shorne Wood. Sample SW 23 yielded an impoverished microflora which includes both fresh-water and marine microplankton.

Above the carbonaceous sands are ferruginous, shelly sands, lightly cemented at the base (SW 24). These are overlain by typical Woolwich Shell Beds which contain abundant

Figure 2.6

SWANSCOMBE TQ 598728 Composite section



Key: See Figure 2.4

molluscs and microfloras comparable with those recorded at Charlton and Shorne Wood. Microfloras from the adjacent Swanscombe Park road cutting were described by Gruas-Cavegnetto (1970). Within the Shell Beds is a discontinuous band of grey-green marl, up to 7.5cm (3") thick (SW 33), which contains a rich microflora with the fresh to brackish-water colonial alga Pediastrum. From this band in the Swanscombe Park road cutting Curry (1962) obtained a fauna which includes very small molluscs, Planorbis hemistoma, Bithinella websteri and Lapparentia pygmaea. He also recovered oogonia of Charophytes identified as a new species of Stephanochara, a genus previously unknown below the upper Eocene (Curry 196/ , p.262).

The fossiliferous Shell Beds are overlain by c.1.20m of laminated grey clay and fine sand which are intensely bioturbated (SW 38). These may be equivalent to the laminated beds at the base of the Striped Loams at Charlton.

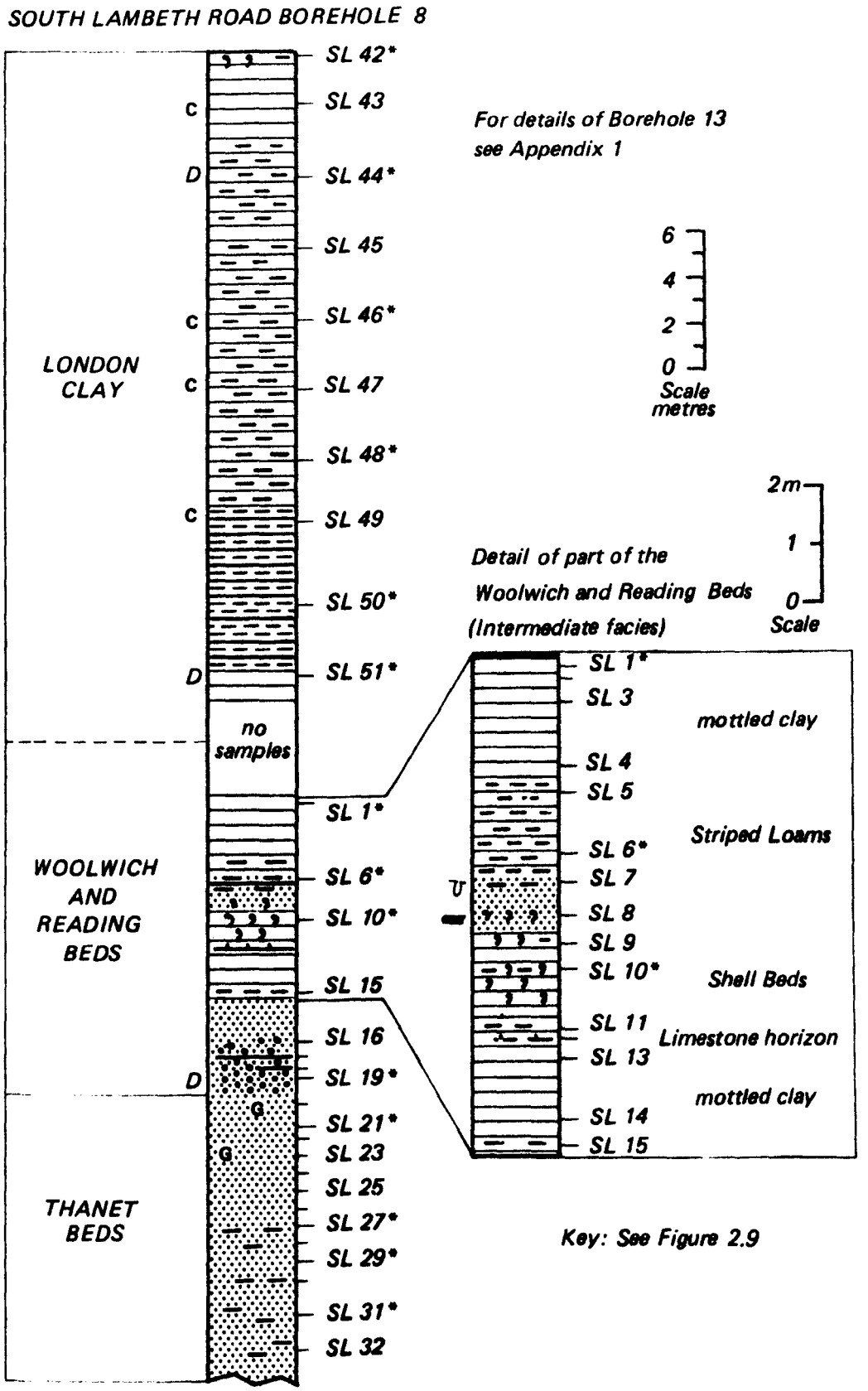
The remainder of the sequence was not accessible at the time samples were collected but has been exposed by later excavations. The laminated clays in the Woolwich Beds are succeeded by an unnamed sand unit which contains very well-preserved Ophiomorpha burrows in the lower part (suggesting marine conditions of deposition) but locally, in the highest metre, another carbonaceous horizon occurs similar to that beneath the Shell Beds. Small, brown, carbonaceous clasts occur within the sand along the sets of small-scale cross-bedding. A thin clay unit overlies these sands and has been carried down into them by bioturbation.

Oldhaven Beds and London Clay.

King (1981) refers the Oldhaven Beds at this locality to the Herne Bay Member of the Oldhaven Formation (see Figure 1.5) and, in the overlying London Clay Formation, recognises both the Swanscombe and Walton Members (Divisions A1 and A2 respectively).

GROUP 3; contains the two boreholes, South Lambeth Road, London (SL) and Leaden Roding, Essex (LR) which have sequences of thick Thanet Beds, Woolwich and Reading Beds of

Figure 2.7


SOUTH LAMBETH ROAD BOREHOLE 8
SL 42*
SL 43
SL 44*
SL 45
SL 46*
SL 47
SL 48*
SL 49
SL 50*
SL 51*
C
D
C
C
C
D
LONDON CLAY
no samples
WOOLWICH AND READING BEDS
SL 1*
SL 6*
SL 10*
SL 15
SL 16
SL 19*
SL 21*
SL 23
SL 25
SL 27*
SL 29*
SL 31*
SL 32
D
G
G
THANET BEDS
For details of Borehole 13 see Appendix 1
6
4
2
0
Scale metres
2m
1
0
Scale
Detail of part of the Woolwich and Reading Beds (Intermediate facies)
SL 1*
SL 3
SL 4
SL 5
SL 6*
SL 7
SL 8
SL 9
SL 10*
SL 11
SL 13
SL 14
SL 15
U
mottled clay
Striped Loams
Shell Beds
Limestone horizon
mottled clay
Key: See Figure 2.9

Intermediate or Reading Facies and London Clay (Appendix 1. Table 6).

SOUTH LAMBETH ROAD BOREHOLES:TQ 304772

Mr.A.D.King kindly gave me splits of samples from Boreholes 8 and 13 drilled in the South Lambeth Road, London during 1968.

The sequence in Borehole 8 ranges from Thanet Beds through the Woolwich and Reading Beds (c.12m) into the London Clay, 25m+ (Figure 2.7).

Thanet Beds.

The Thanet Beds comprise c.10m of glauconitic, fine silty sands; no distinct shelly horizons are recognisable. Microfloras are generally sparse to moderately rich although a few samples were barren of palynomorphs.

Woolwich and Reading Beds.

The base of the Woolwich and Reading Beds is marked by a clear pebble bed which, at the base, has a matrix of glauconitic sand (SL 19 which has a moderately rich microflora) and above, a matrix of mottled sandy clay (SL 18-SL 16). Above the pebble bed is an unnamed sand unit which was not sampled. The rest of the Woolwich and Reading Beds are in the Intermediate facies with mottled clay (samples SL 15-SL 11) followed by typical Shell Beds (SL 10-SL 8), ?Striped Loams (SL 6 and SL 7) and a second lense of mottled clays (SL 5- SL 1). The mottled clays are either barren or contain very sparse palynomorphs, the Shell Beds and ?Striped Loams contain rich and diverse microfloras.

In Borehole 8 no samples were available from the highest part of the Woolwich and Reading Beds but this interval is covered by samples from the neighbouring Borehole 13. Here an upper lense of Shell Beds occurs (SL 40). The presence of an Upper Shell Bed is typical of the Intermediate facies in this area, as is the development of the thin, freshwater limestone, the Paludina Band within it (Hester 1965, Berry & Cooper 1977, see Figure 1.5 herein). Although the Paludina Band is present in Borehole 13 (Mr. A.D. King personal communication) samples were not available for analysis.

London Clay.

Samples were studied at c.6m intervals through the London Clay (SL 51-SL 42); all are clays or silts and contain moderately rich assemblages.

LEADEN RODING BOREHOLES, Essex: TL 594136 (Table 7 in Appendix 1).

The Essex River Authority drilled two boreholes at Leaden Roding during 1970 and this material was kindly made available to me in October of that year. The first borehole (TL 594136) penetrated London Clay (c.21m), Woolwich and Reading Beds (c.12m) including the Reading facies and entered the top of presumed Thanet Beds. The second, adjacent borehole continued through the Thanet Beds and bottomed in Chalk (Figure 2.8 and Table 7 in Appendix 1).

Material from both boreholes has been used to give complete cover from the Chalk through to the London Clay, with a fairly wide sample interval (c.2.5m-5m) throughout.

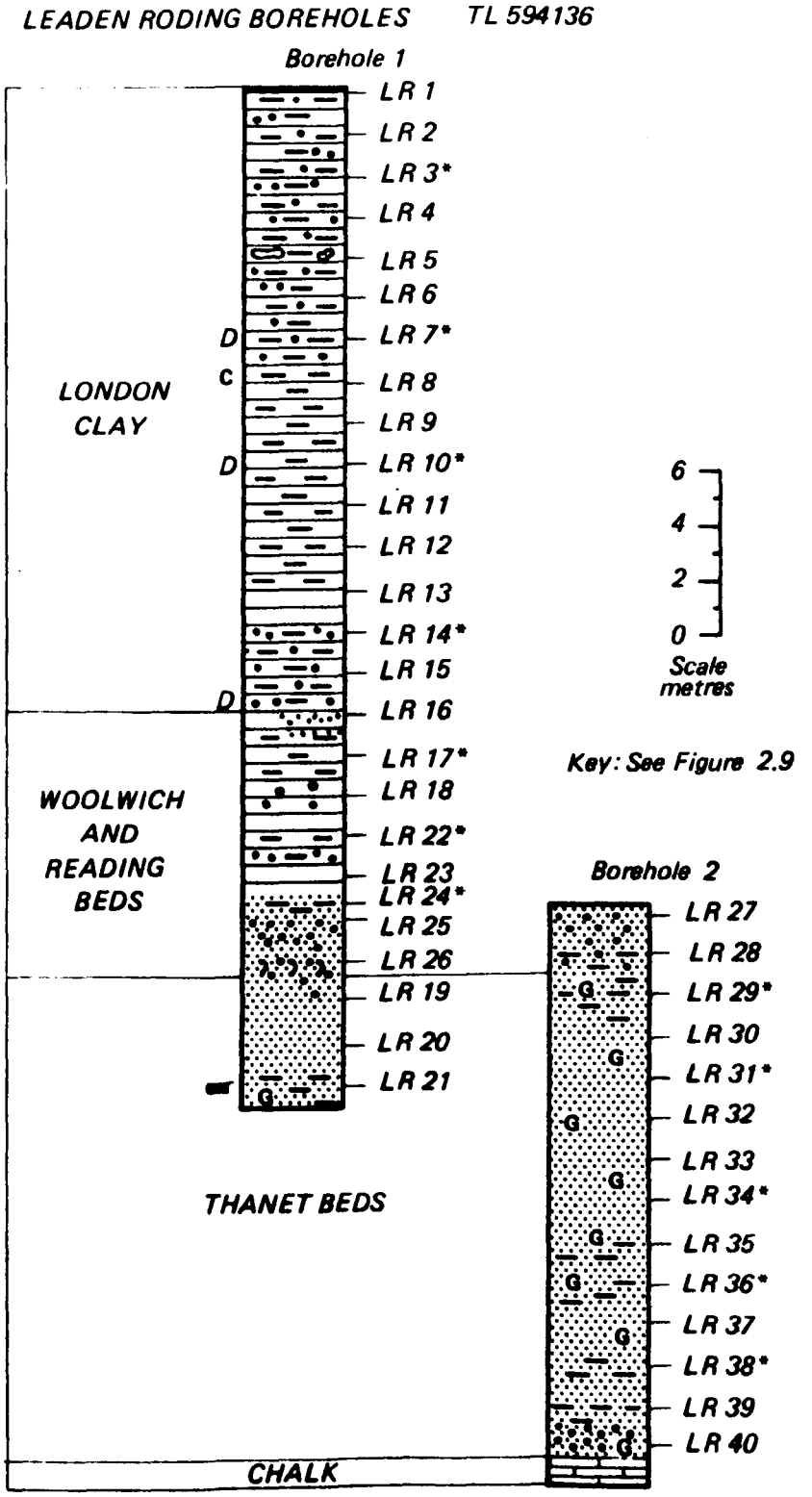
Thanet Beds.

The basal 18m are presumed to be Thanet Beds with the Bullhead Bed at the base. They comprise glauconitic and silty sands, greenish-grey in colour and underlie a mottled, reddish-brown and yellow pebbly sandstone which is interpreted as the Bottom Bed of the Woolwich and Reading Beds. Microfloras typcial of the Thanet Beds occur in the samples LR 34, LR 36 and LR 38 but those from higher levels (LR 31 and LR 29) are too sparse to be diagnostic (Chapter 5).

Woolwich and Reading Beds.

The boreholes lie within the belt of the Reading facies of the Woolwich and Reading Beds as depicted by Hester (1965) (Figure 1.4). Certainly the Shell Beds typical of the Woolwich facies are not present here and the basal pebble bed is overlain by a series of silty sands with scattered flint pebbles and by clays, mottled in part, which resemble the Reading facies. Microfloras are generally sparse (LR 24, LR 22) but samples contain rare dinoflagellates, evidence of marine influence during deposition. Sample LR 22 contains very rare elements which are more typical of the Woolwich

Figure 2.8


LEADEN RODING BOREHOLES TL 594136
Borehole 1
LR 1
LR 2
LR 3*
LR 4
LR 5
LR 6
D
LR 7*
C
LR 8
LONDON CLAY
LR 9
D
LR 10*
LR 11
LR 12
LR 13
LR 14*
LR 15
D
LR 16
LR 17*
LR 18
WOOLWICH AND READING BEDS
LR 22*
LR 23
LR 24*
LR 25
LR 26
LR 19
LR 20
LR 21
G
THANET BEDS
CHALK
6
4
2
0
Scale metres
Key: See Figure 2.9
Borehole 2
LR 27
LR 28
G
LR 29*
LR 30
G
LR 31*
G
LR 32
LR 33
G
LR 34*
G
LR 35
G
LR 36*
G
LR 37
LR 38*
LR 39
G
LR 40

than the Reading facies (Pistillipollenites mcgregorii and Pentaporoites belgicus).

London Clay.

The exact junction with the London Clay is not clearly defined lithologically but has been taken at the more pebbly horizon LR 15. Typical London Clay, olive grey and brownish grey silty clays, occur at LR 14 and above and have yielded moderate to abundant microfloras. Rare, pyritised diatoms were recovered from LR 16, LR 10 and LR 7. The assemblage recovered from LR 17 appears to be transitional between the Woolwich and Reading Beds and the London Clay.

GROUP 4, comprises sections in the west of the London Basin in which Reading Beds (Bottom Bed and Reading facies) are present; Pincents Kiln (PK), a temporary exposure adjacent to the M4 motorway north-west of Reading (M4) and several localities from which isolated samples of the Reading Beds were examined; Waterloo Kiln in Reading (WK), Knowl Hill north-west of Reading (KH) and Cold Ash Quarry near Newbury (NB).

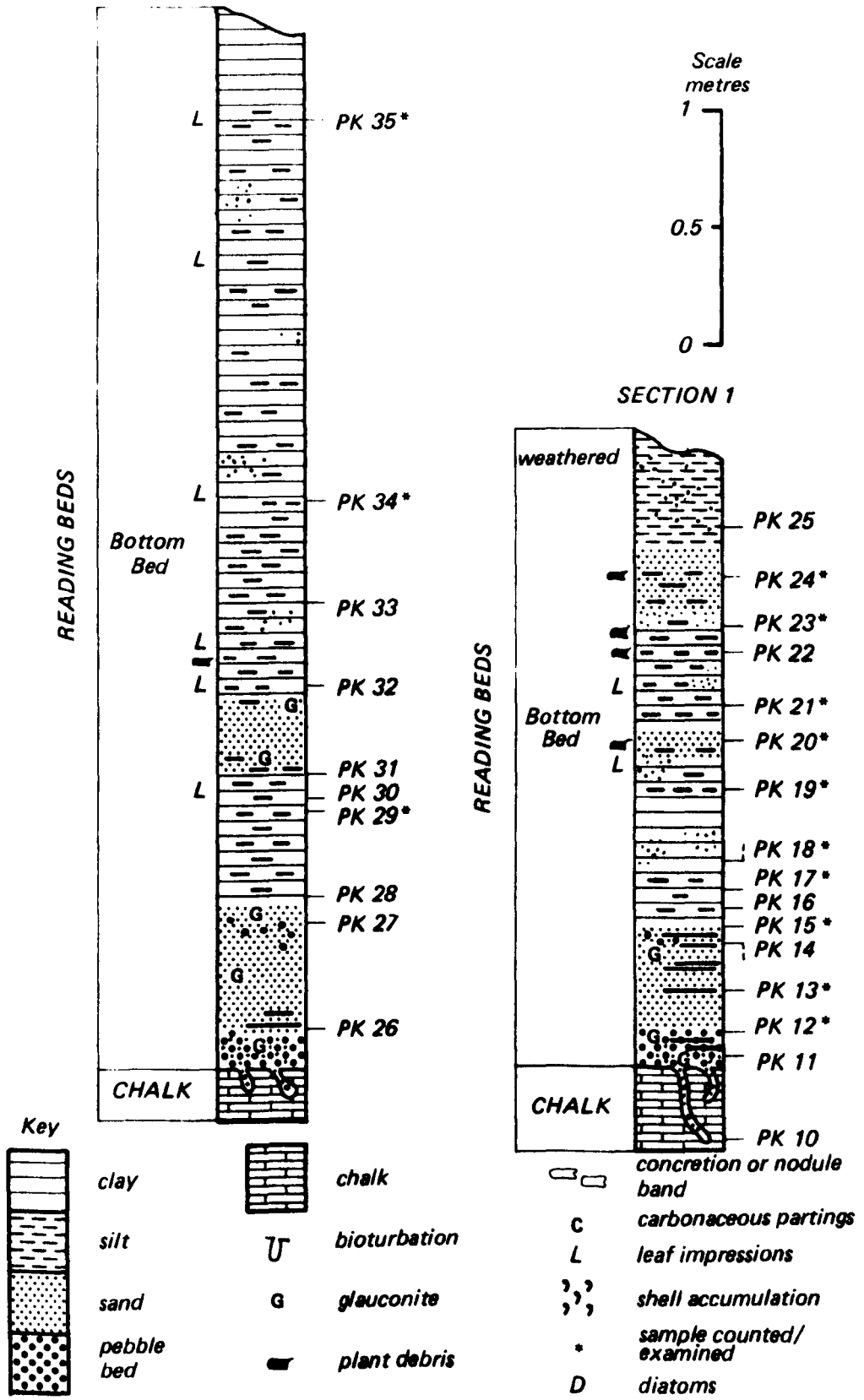
PINCENTS KILN: SU 653722 (Table 8 in Appendix 1).

As stated above (Section 1.3 p.24) the sequence in the Reading Beds at Pincents Kiln (c.4.5m) is very similar to that described near Theale by Hawkins (1946).

In Section 1 (Figure 2.9) the glauconitic sands (PK 11-PK 15) and silty clays (PK 17 and PK 18) at the base of the Reading Beds contain impoverished microfloras, too sparse to count. They probably correspond to the Bottom Bed as defined by Hawkins (1955). The grey silty clays above (which contain common, fragmentary angiosperm leaves and charcoal fragments) and the associated silty sands (PK 20 to PK 24) generally yield rich microfloras including rare acritarchs and very rare dinoflagellate cysts, indicating brackish and possibly marine influences during deposition.

Section 2 has a thicker development of the upper silty clay unit; moderately rich microfloras, with rare acritarchs were recovered from it (PK 29, PK 34 and PK 35).

Figure 2.9


PINCENTS KILN SU 653722
SECTION 2 (22.5m southeast of Section 1)
READING BEDS
Bottom Bed
CHALK
L
G
PK 35*
PK 34*
PK 33
PK 32
PK 31
PK 30
PK 29*
PK 28
PK 27
PK 26
Scale metres
1
0.5
0
SECTION 1
weathered
READING BEDS
Bottom Bed
CHALK
PK 25
PK 24*
PK 23*
PK 22
PK 21*
PK 20*
PK 19*
PK 18*
PK 17*
PK 16
PK 15*
PK 14
PK 13*
PK 12*
PK 11
PK 10
Key
clay
silt
sand
pebble bed
chalk
bioturbation
glauconite
plant debris
concretion or nodule band
carbonaceous partings
leaf impressions
shell accumulation
sample counted/ examined
diatoms

ISOLATED SAMPLES FROM THE READING AND NEWBURY AREA.

Several isolated samples were processed from the Reading Beds from the western end of the London Basin.

M4 MOTORWAY near Reading (Appendix 1, Table 9).

During the construction of the M4 Motorway west of Reading in 1971 various horizons of the Reading Beds were exposed in cuttings or in sand pits adjacent to the carriage-way.

Samples were collected from several localities including; (i) lenses of pale yellowish grey clay from within cross-bedded sands from the vicinity of Furze Hill, north of Newbury (SU 512740) and elsewhere (e.g. SU 499741); (ii) typical mottled clay from the cutting north of Coombe Wood (SU 551737) and (iii) glauconitic sands and the basal pebble bed from a section north of Bussock Wood (SU 467728), north of Newbury. These were all either barren or yielded only sparse palynomorphs.

In the section north of Hewins Wood (SU 601738) west of Reading, (Figure 2.10) about 3m of the Bottom Bed were exposed, including the Ostrea bellovacina Bed. This is a glauconitic sand which is full of oysters and yielded a sparse microflora including rare acritarchs and dinoflagellates (M4/7(1)). The silty clays higher in the sequence are generally ironstained, have leaf impressions at some horizons and show some evidence of bioturbation. Only very sparse microfloras were obtained from this unit.

WATERLOO KILN, Reading, Berkshire. (Appendix 1, Table 10).

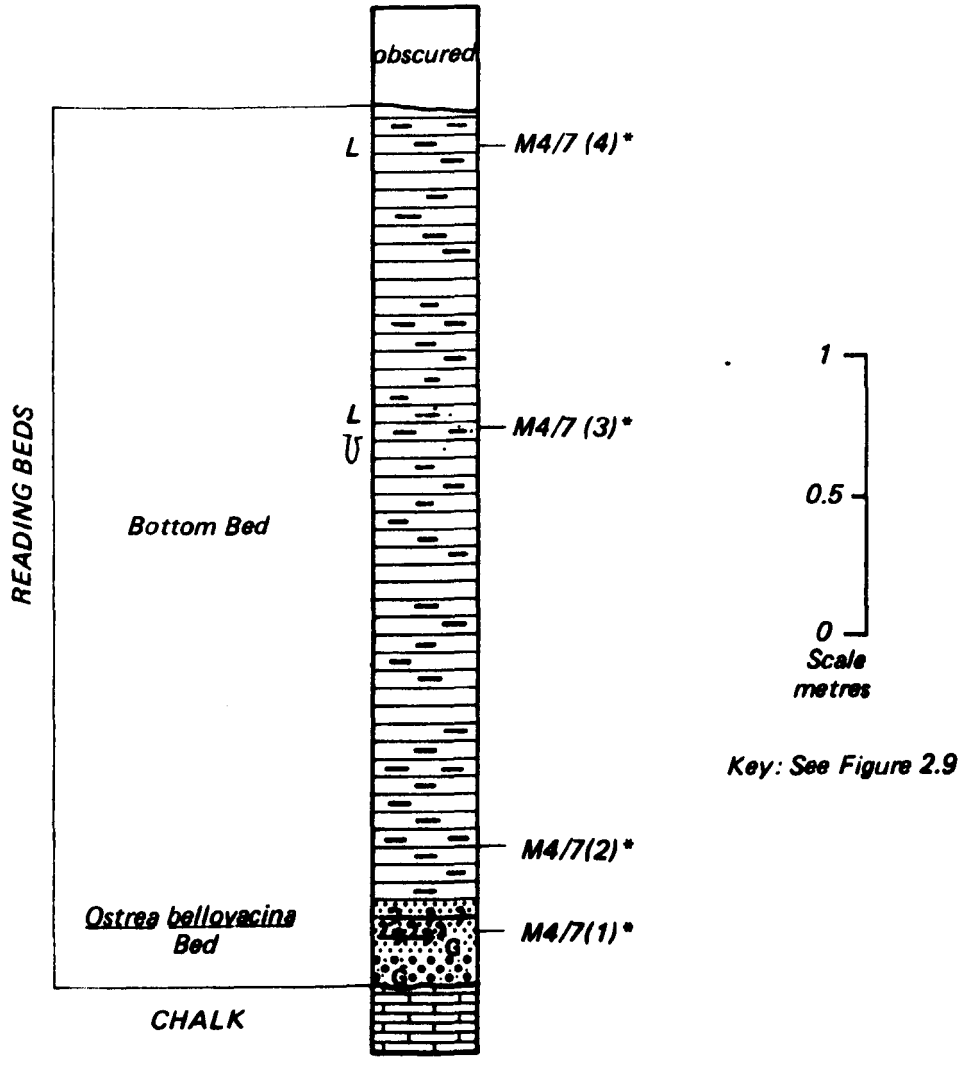
Leaf impressions from the Reading Leaf Bed were collected from this section by Professor (then Mr.) W.G. Chaloner in 1952. The exposure has since been filled in and built over. My sample, WK (a pale, yellowish brown, sandy silt) was taken from the matrix of one of these specimens (B.M.N.H. reference number V. 56968). It contains a moderately diverse microflora including extremely rare acritarchs,

KNOWL HILL SAND PIT near Reading, Berkshire: SU 819798 (Appendix 1, Table 11).

Five samples were collected in 1971 from the mottled clays in this sequence. They range in colour from dark grey through red to grey green and are quite rich in haematite. (Not recorded in Appendix 1). None of them yielded

Figure 2.10

M4 MOTORWAY (c.0.25 Km north of Hewins Wood) SU 601738



palynomorphs. The underlying Reading Leaf Bed was not visible at that time but it had been exposed during the construction of a drainage trench in 1960 and a sample was collected then by Mr. R. Ashfield; R 1154 in Prof. W.G. Chaloner's collection (=KH herein). This sample contains a moderately rich microflora including some acritarchs.

COLD ASH QUARRY, near Newbury, Berkshire: SU 501713 (Appendix 1, Table 2).

Dr. P.R. Crane is currently working on plant macrofossils, particularly fruit, seeds and leaves from this locality. The fossils occur in clay and silt pockets within cross-bedded sands of the Reading Beds, between c.5m and c.15m above the Chalk. In 1976 he sent me two samples of silty claystone, both containing angiosperm leaf remains, so that the macro- and micro-floras might be compared. NB 1 is a light olive grey silty claystone and NB 2 a yellowish grey silty claystone. Both contain rich microfloras which include very rare acritarchs.

ISLE OF WIGHT.

ALUM BAY, Isle of Wight: SZ 305853 (Appendix 1, Table 13).

Samples were collected during a Geologists' Association field trip in May 1974, led by Messrs A.D. & C. King. Spot samples were taken from each of the Divisions A to D of the London Clay Formation as defined by Mr. C. King and the measured section (Figure 2.11) is based on the diagram he produced for participants (see also King 1981, Fig.31).

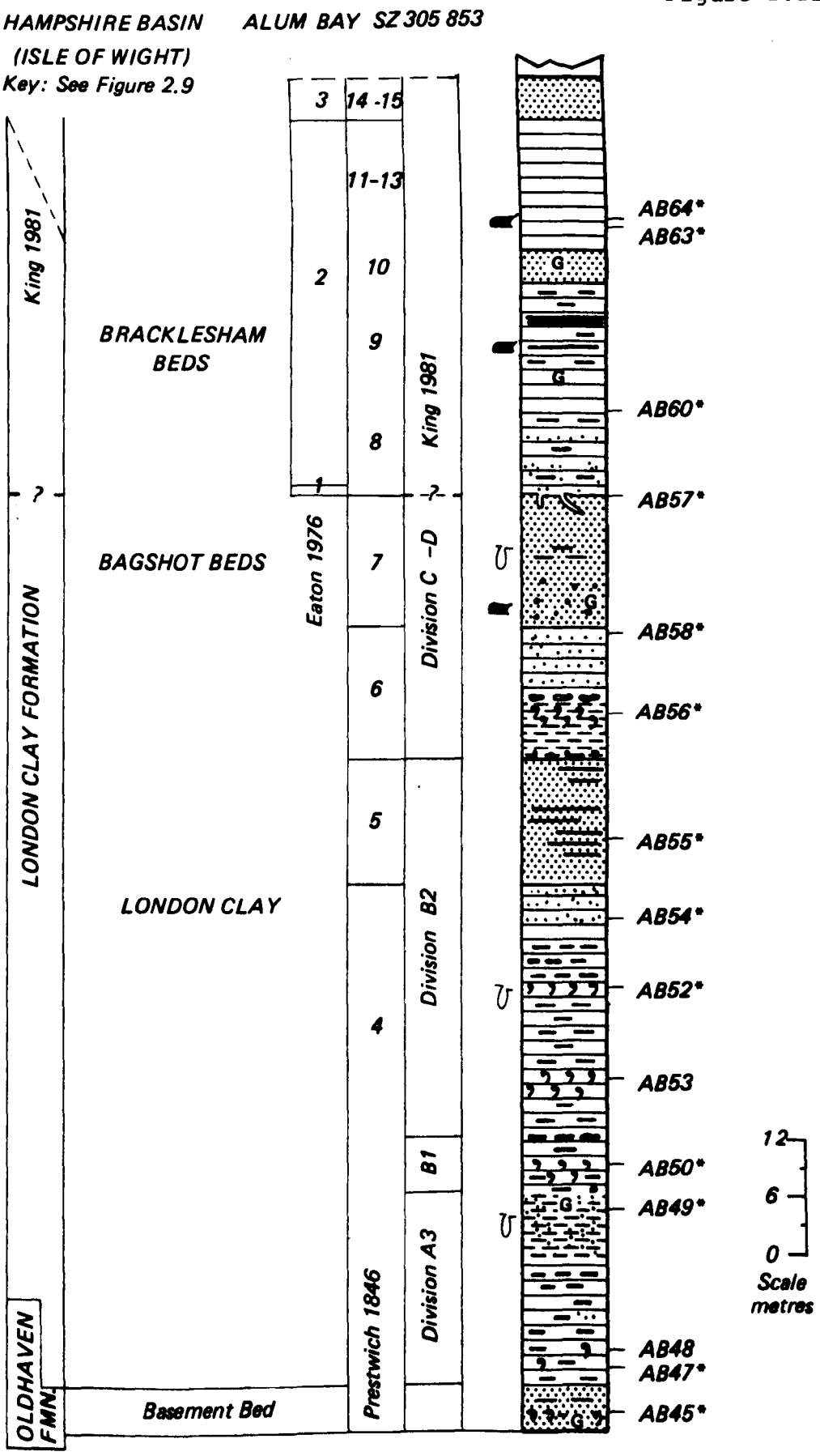
Reading Beds and Oldhaven Formation.

Five samples were processed from the Reading Beds at Alum Bay but they were either barren or contained only one or two palynomorphs. One sample was examined from the Oldhaven Formation (sensu King 1981) and contained a moderately diverse microflora (AB 45).

London Clay.

The London Clay at this locality comprises a series of transgressive/regressive cycles, the regressive phase becoming more pronounced towards the top of the sequence

Figure 2.11


HAMPSHIRE BASIN
(ISLE OF WIGHT)
Key: See Figure 2.9
ALUM BAY SZ 305 853
King 1981
BRACKLESHAM BEDS
BAGSHOT BEDS
LONDON CLAY FORMATION
LONDON CLAY
OLDHAVEN FMN.
Basement Bed
Eaton 1976
3
2
1
?
Prestwich 1846
14-15
11-13
10
9
8
7
6
5
4
King 1981
Division C -D
Division B2
B1
Division A3
AB64*
AB63*
AB60*
AB57*
AB58*
AB56*
AB55*
AB54*
AB52*
AB53
AB50*
AB49*
AB48
AB47*
AB45*
G
12
6
0
Scale metres

(King 1981). The exact position of each sample above the base of the London Clay was not recorded but several come from clearly defined horizons (King 1981, Fig. 33); AB 47 from the Astarte horizon near the base of Division A3; AB 50 from the equivalent of the Planktonic Foraminiferid Datum of Wright (1972); AB 53 from the Pinna horizon within Division B2; AB 56 from the Glycimeris horizon within Division C. Samples AB 47 to AB 56 contain rich microfloras with a high percentage of reworking. There is a marked change in the microflora at AB 58 and above and reworking becomes rare (Chapter 5).

Bracklesham Beds.

Samples AB 57 to AB 63 are from the Bracklesham Beds as defined by Eaton (1976). AB 57 is from the base of Eaton's Bed 1 and sample AB 63 and AB 64 come from the laminated beds within Eaton's Bed 2. Messrs. A.D. & C. King consider this unit to be transitional between the London Clay and Bracklesham Formation (personal communication).

Isolated samples were examined from higher in the succession to establish whether there are any marked floral changes above the London Clay. AB 68 is from a horizon considered by Mr. A.D.King to be equivalent to Fisher's Bed IV of the Whitecliff Bay section and AB 70 is from the Leaf Bed which he considers to be roughly equivalent to Fisher's Bed VIII. Both yielded rich microfloras (Chapter 5 and Appendix 2).

2.2 PROCESSING OF SAMPLES.

Collection.

Most of the lithologies collected are soft sediments. Sections were cleaned with a spade or trowel to expose unweathered rock as far as possible. Samples were then collected with a clean trowel and placed in labelled heavy duty polythene bags which were sealed by a double fold and secured by several staples.

Processing.

The processing techniques used were intended to extract the maximum number of palynomorphs from the sediments. Since the lithologies involved vary from moderately clean

sands to organic rich clays and lignites there seemed little point in standardising the amount of sediment processed, much larger samples were used of the sands from the Thanet Beds, Woolwich Bottom Bed and other unpromising lithologies than of the clays, such as the London Clay and Woolwich Shell Beds.

In recent years there has been much interest in the total organic content of sediments including the organic debris other than palynomorphs. This investigation however deals only with the palynomorphs and no attempt was made to preserve the other organic debris.

Samples other than lignites.

The basic technique involved the removal of carbonates with hydrochloric acid (HCL); removal of silicates with cold hydrofluoric acid (HF); treatment with hot hydrochloric acid to remove any calcium flouride which might have formed during HF treatment; heavy liquid separation using zinc bromide solution at specific gravity 2.0; oxidation with concentrated nitric acid ± alkali treatment; mounting in glycerine jelly ± Safranin O stain.

The procedure adopted was as follows:-

1. For clays and siltstones a piece was cut from the centre of a block, broken into small pieces (less than 5mm) and placed into a polypropylene beaker or test-tube. Unconsolidated sands were placed directly into a beaker.
2. The sample was tested for reaction with 10% HCL. If this was positive conc. HCL was added and left until the reaction ceased. If the reaction was vigorous or prolonged the HCL was changed several times. The sample was washed until neutral in distilled water.
3. Cold HF (40%) was added, the sample was stirred, covered and left overnight or longer. Breakdown was usually rapid, when the sample stood in HF for longer periods the reaction had usually ceased within the first few hours. It was rarely necessary to change the HF. The HF was decanted and the sample washed in distilled water by centrifugation until neutral.
4. Conc. HCL was added and the sample was heated in a water-bath to remove any calcium fluoride which might have

formed during HF treatment. After being neutralised a water mount was checked for total organic content. Where organic debris was abundant and occurred as clumps containing minerals oxidation preceeded the heavy liquid separation (flotation). Some of the very organic sediments in which most mineral was removed by HF treatment were not floated (e.g. Woolwich Shell Beds from Shorne Wood).

5. Concentrated nitric acid was added to the residue, stirred and either left to stand for several minutes or was diluted after a few seconds and the sample was centrifuged immediately. The liquid was decanted and the sample washed several times in distilled water. Oxidation was usually followed by alkali treatment. After washing, 5-25% ammonia solution was added to the residue which was stirred, left to stand (c.30 secs. to c.30 mins.), then diluted, centrifuged and the liquid decanted. The residue was washed several times in distilled water.

6. After centrifugation the residue was transferred to one or more small glass test tubes (15ml). Zinc bromide solution of 2.0 specific gravity was added and the sample was stirred then shaken vigorously until the sediment was thoroughly dispersed.

7. Samples were centrifuged at c.2,500r.p.m. for 15 mins. to effect separation.

8. The upper organic fraction was pipetted into one or several large, clean test-tubes which were then filled with distilled water to which one or two drops of diluted HCL were added. The sample was centrifuged to concentrate the organic fraction in the bottom of the tube, the liquid was decanted and the residue washed twice more in distilled water by centrifugation. During this process a water mount was examined to gauge the abundance of palynomorphs.

9. After the final centrifugation the liquid was decanted and the test tube inverted over a filter paper to allow the last drops of water to run out. Several drops of warm glycerine jelly (either unstained or stained with "Safranin O") were added to the residue and stirred gently. One or two drops of the residue were then pipetted onto slides, coverslips were added and the slides were gently warmed on a hot plate to allow the glycerine jelly to spread to the

edge of the coverslip. The remainder was transferred to storage tubes. Slides were sealed with clear nail polish or paraffin wax.

Lignites (Shorne Wood Section).

The friable lignites from the south side of the carriage-way were broken into small pieces (c.5mm) and placed in a glass beaker. 5% KOH was added and left for c.2 hours. Small portions of the residue were taken, neutralised and water mounts checked periodically. Samples JL 865, 866 and 867 broke down in 2 hours, JL 864 took 8 hours. The samples were then neutralised and passed through a coarse sieve (177 microns) to separate large pieces of plant debris including megaspores and seeds. The fine fraction of JL 866 was washed and mounted in glycerine jelly. The other samples were placed in 40% HF overnight before being neutralised, washed and mounted. The wet coarse fractions were examined under a low power binocular microscope, seeds and megaspores were picked out and mounted in glycerine jelly.

The more brittle lignites from the north side of the carriage-way needed treatment with concentrated nitric acid (JL 879 for 2 hours, JL 877 overnight) followed by 6% ammonia solution for 5 minutes before washing and mounting. JL 869 was treated with concentrated nitric acid for one hour followed by 1½ hours of Schulze's Solution, before ammonia treatment as above.

Comments on the processing technique used.

The use of micromesh sieves of various designs has become increasingly popular and is an extremely useful technique for the concentration of palynomorphs and the production of clean preparations free from the very fine organic debris which can obscure palynomorphs and make examination of slides so laborious (Neves & Dale 1963, Streel 1965). Nevertheless,at the time this investigation was begun I felt that, with the small size of much of the angiosperm pollen and many of the acritarchs present in the Tertiary samples, there was a real danger of losing material. Consequently I decided not to sieve samples which were to be counted although at a later date samples CH 6E, PB 13E and PB 16E were sieved with a 10 micron nylon sieve to provide cleaner specimens for photography.

2.3 COUNTS.

Smith & Butterworth summarise some of the published views on the validity of palynological counts (1967, p.105, 106). Various authors suggest that between 150 and 1,000 individuals should be counted if the results are to be representative of the total assemblage although Barkley (1934, p.288) sees no advantage in counting more than 200 specimens and Dimbleby (1957, p.14) demonstrates graphically that the rate of increase of species recorded declines rapidly after about 250 specimens have been counted. He finds that all species present at 1% or more are recorded within the first 250 grains.

Cross (1950, p23) suggests the diversity of the flora and the relative abundance of individuals should also be considered in determining the size of a count. This is a view supported by Wilson (1959). He states that a sample will be sufficiently analysed if between 150-200 grains are counted but, where many species are present, or where one or two species are very abundant, the less abundant taxa may not be recorded in the first 200 grains. He describes a species-spectrum curve in which the number of specimens counted is plotted against the number of species recorded. The curve trends upwards as the number of species observed increases with additional counted specimens. When the number of species in the assemblage is nearly exhausted the curve flattens strongly. After this "break-off point" few additional species will be added regardless of the number of specimens counted.

Preliminary examination of samples from the Shorne Wood and Pincents Kiln sections showed that several lithologies contain rich and diverse microfloras. It seemed unlikely that a count of 250 individuals would be representative of the microfloras as a whole. Species-spectrum curves were therefore plotted for samples from the lignite and the Woolwich Shell Beds at Shorne Wood (JL 867 and JL 887 respectively) and from the Reading Beds at Pincents Kiln (PK 4).

As expected the "break-off point" occurred earliest in the least diverse assemblage, the Woolwich Beds Lignite, JL 867 (Figure 2.12), after a count of 230 when 24 species

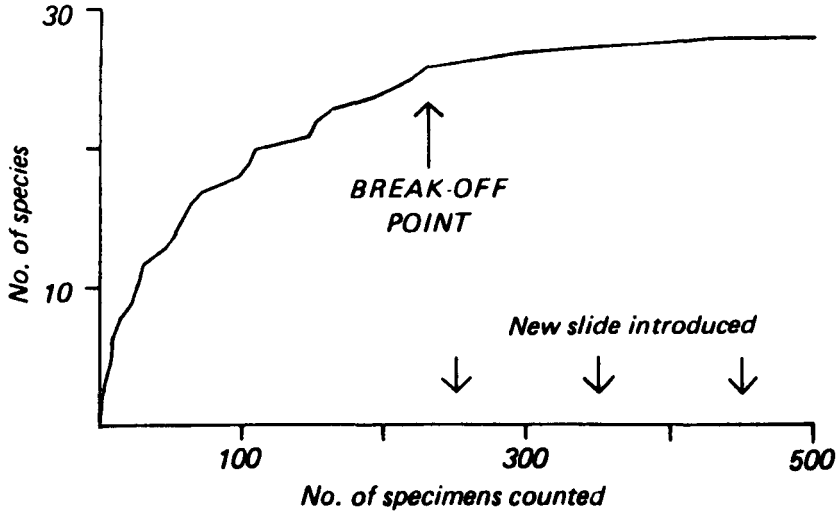


Figure 2.12 *Species spectrum curve for sample JL 867: Woolwich Beds lignite*

had been recorded; only 4 additional species were recorded after a total count of 450 specimens. In contrast, the other samples needed counts well over 250 to reach "break-off point"; it occurred at 810 in PK 4 (after 65 species had been recorded, Fig. 2.13) and at 1,200 in JL 887 when 95 species were recorded (Fig. 2.14). Clearly a count of 250 grains would not record all of the species present in these assemblages.

Nevertheless it is impracticable to count as many as 1,000 specimens for every sample. From consecutive counts of 250 grains (recorded during the count of 1,500 on sample JL 887) it is clear that the relative abundance of the commoner taxa is established during a count of the first 250 specimens. The problem lies with the rarer taxa which are important as evidence of the diversity of the microflora, which may be useful in establishing local and regional elements of the flora or may be of stratigraphical value. But it is well known that many variables influence the distribution and preservation of palynomorphs in

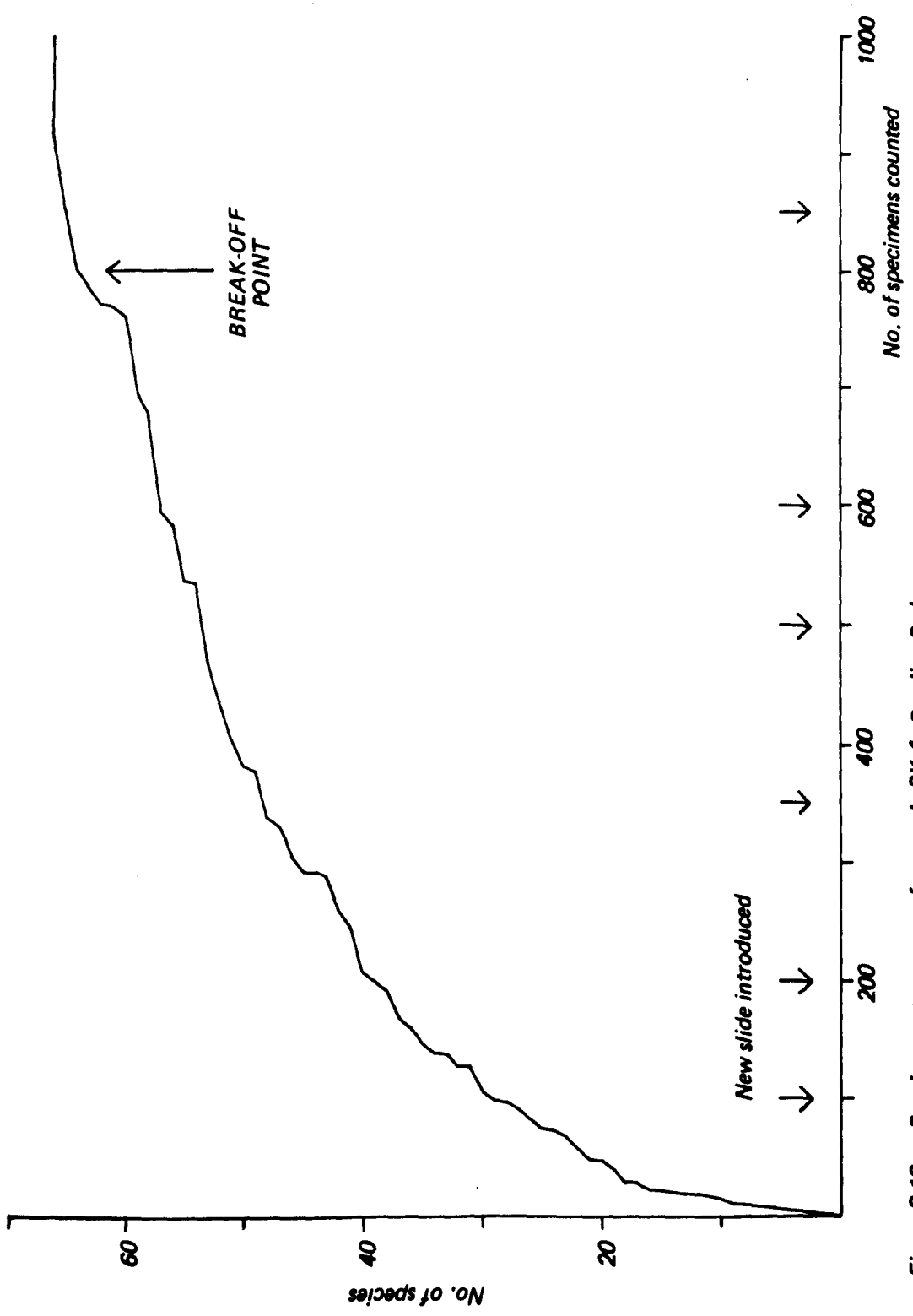


Figure 2.13 Species spectrum curve for sample PK 4: Reading Beds.

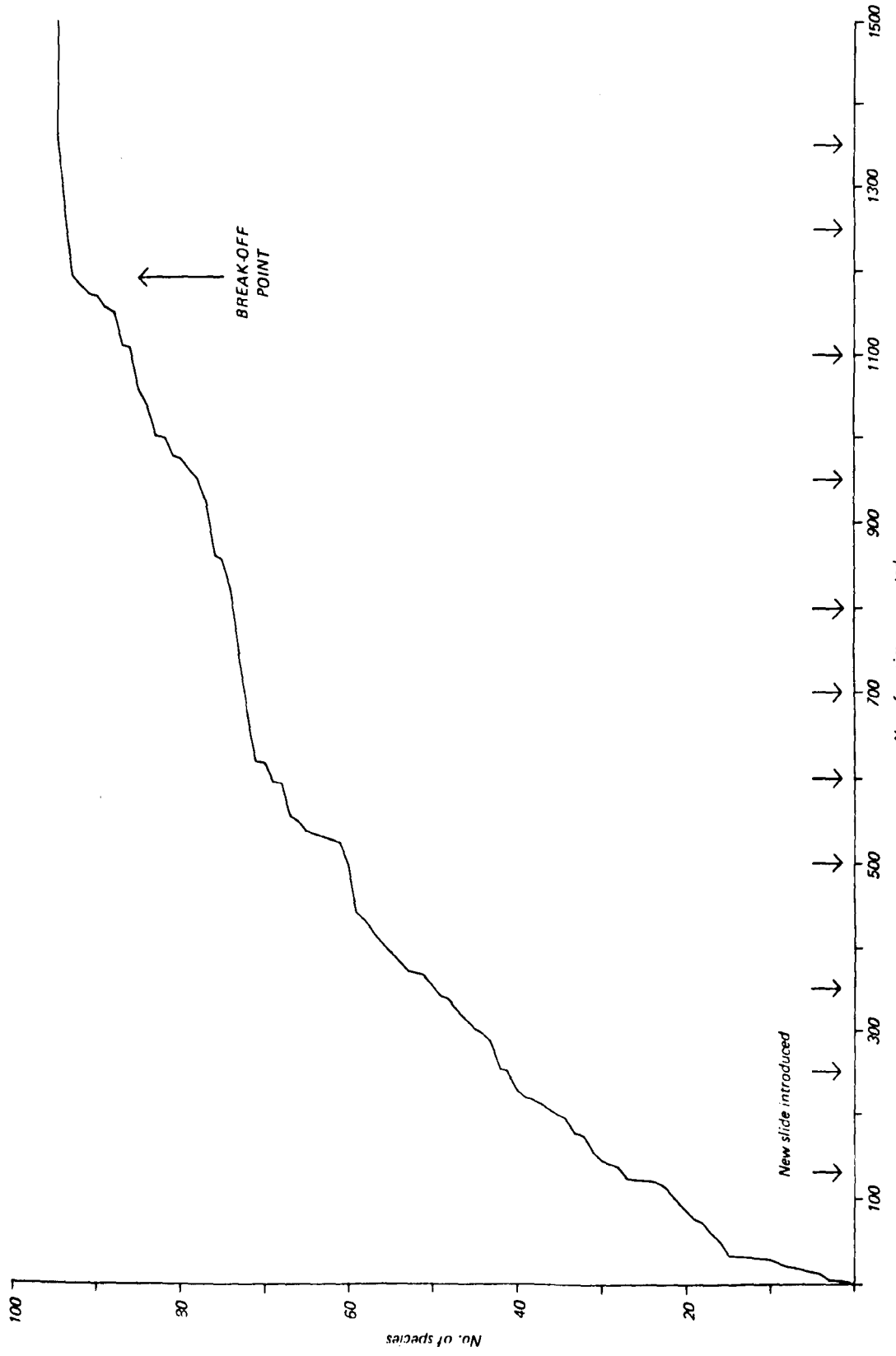


Figure 2.14 Species spectrum curve for sample JL 887: Woolwich Shell Beds.

sediments (see Chapter 5) and a combination of these factors diminishes the value of accurate percentage data for rare taxa, a simple record of their presence or absence is equally useful.

The following method was therefore adopted in order to establish the relative abundance of the common taxa but also to record as many of the rarer taxa as possible. Firstly 250 spores and pollen were counted (at a magnification of x 400 with x 1000 for specific identification as necessary). Then one or more extra slides were scanned at a lower magnification (x 100 with higher magnification as necessary) to record any additional species. This is not quantitative and the number of additional specimens scanned depended entirely on the richness and diversity of each sample.

Although this investigation deals primarily with spores and pollen it was considered important to have some record of the acid resistant microplankton also present. During the initial count of 250 spores/pollen any dinoflagellate cysts and acritarchs or other algae encountered were recorded. The number of microplankton counted per 250 pollen and spores is consequently very variable, ranging from 0 in JL 864 (Woolwich Bed Lignite) to 708 in PB 8 (Thanet Beds). It was then possible to express each spore/pollen taxon as a percentage of the total spores and pollen, similarly microplankton as a percentage of the total microplankton. Total spores/pollen and total microplankton were also recorded as percentages of the total microflora, but these data are strongly influenced by processing techniques and should be treated with caution (see Chapter 5). The results of the counts are presented in Chapter 5 and Appendix 2.

2.4 PHOTOGRAPHY.

Transmitted light was used for routine photography and taxonomic studies but several taxa were also examined and photographed with the scanning and transmission electron microscope.

Strew mounts and single spore mounts used for photography are in the author's private collection, as are the S.E.M. stubs, specimens used for scanning electron

photomicrographs which were later mounted in glycerine jelly and T.E.M. grids. The slide number and England Finder location for each specimen illustrated by transmitted light are given on the plate explanations.

Transmitted Light.

The taxonomic studies were made on specimens in strew mounts, examined by transmitted light; most of the illustrated specimens come from these slides. Only a few single spore mounts were made since many of the more significant taxa occur in low numbers and are not easy to locate at low power on an open strew mount, their small size also makes handling difficult.

Light photomicrographs were taken using a Zeiss photomicroscope and Pan F or FP 4 black and white film. Most were printed at a magnification of x 1000. (See plate explanations).

Scanning Electron Microscopy.

The scanning electron microscope has been used for the study of several fossil angiosperm species (Kedves & Stanley 1976a, b; Kempf 1973; Laing 1975; Rouse & Srivastava 1970; Stanley & Kedves 1975) and gives useful additonal morphological data, particularly on the external ornament of individual taxa. Unfortunately it is not always easy to identify specimens from scanning electron micrographs alone, particularly the less distinctive triporate/triatriate pollen and small tricolpate/tricolporate grains where aperture type and internal exine features are of greater importance for specific identification. The study of fossil pollen grains with the S.E.M. is most useful when the same specimen can also be identified by transmitted light.

Some of my first S.E.M. studies were made on strew mounts; the pollen residue in water was allowed to dry directly onto the stub. Although reasonable photographs were obtained (see Monocolpopollenites tranquillus, Pl.3 fig. 13) it was impossible to recover individual specimens for later examination by transmitted light.

Alternative methods were tried. For species which occur in "clumps" (e.g. Nyssapollenites sp. A) small groups were picked from a watermount with a brush and placed

separately onto a stub. With the larger size of each group and its isolation on the stub it was usually possible to transfer it to a microscope slide and mount in glycerine jelly once S.E.M. examination was complete, although some specimens were lost.

The most successful method for single specimens was to pick them individually using a micro-picker and to mount several grains close together within a grid on a circular glass coverslip the same diameter as the stub. The micro-picker, which was made in the workshop of the Dept. Botany and Microbiology, University College London, is a modification of the device designed by Kidson & Williams (1971). It clamps onto the x10 objective of the palynological microscope so allowing sufficient space for movement between the objective and microscope slide. A single paint brush hair is mounted, with a drop of candle wax, into a thin metal arm which is adjusted manually until the tip of the hair is visible in the field of view. The metal arm can be raised and lowered by means of a knurled screw and the specimen is picked up by the paint brush hair. Several drops of the pollen/spore residue in water were put on a microscope slide and allowed to dry and the coverslip on which specimens were to be mounted was placed towards the end of the same slide. The strew mount was scanned, a specimen selected and transferred to the coverslip using the micro-picker. In most cases no glue was used, but occasionally specimens were mounted in a thin smear of "polyvinylpyrolidone" adhesive. The coverslip was then fixed to the stub with several layers of doublesided "Sellotape" before being coated by evaporation of gold-palladium in a Polaron sputter coater. After study the coverslip was easily removed and mounted on a slide with glycerine jelly for examination by transmitted light. Unfortunately, although very thin, the gold-palladium coating is liable to crack as the specimens are mounted in glycerine jelly. They remain identifiable but are not suitable for photography.

I am grateful to Mr. P.D.Moore for the Dept. of Crystallography, Birkbeck College, for operating the Stereoscan S2 and to Mr. M. Gay (formerly of the Dept. of

Botany and Microbiology, University College London) and Prof. W.G.Chaloner for operating the Cambridge Stereoscan S600.

Transmission electron microscopy.

Kedves & Pardutz (1970, 1973) describe the ultrastructure of several early Tertiary angiosperm species and Kedves and Stanley (1975, 1976a, b) use a combination of S.E.M., T.E.M. and transmitted light for the analysis of their specimens. In their 1970 paper Kedves & Pardutz illustrate nine species but point out that, in order to obtain sufficient material suitable for publication, they needed 5-10 specimens of each species and prepared and studied 150 "blocks" (grains mounted in resin). Kempf (1973) comments on the difficulty of handling dispersed fossil miospores because of their small size and used Miocene Alnus pollen from anthers for his scanning and transmission electron micrographs.

The lignites in the Woolwich and Reading Beds at Shorne Wood contain several whole anthers of Platycaryapollenites platycaryoides as well as abundant dispersed grains. The wall structure of this species is particularly interesting since, when seen in transmitted light it has a series of crossing arcs which appear to be exine thinnings although these are frequently associated with folds. The presence of anthers made this an ideal subject for transmission electron microscope studies. For comparison, dispersed grains were examined with the S.E.M.

Specimens were prepared as follows. After maceration of the lignite, sample JL 865, as described above (Section 2.2, p. 55) the residue was passed through a 124 micron mesh sieve and the coarse fraction was searched for anthers and large clusters of Platycaryapollenites platycaryoides. These were picked, mounted in water and their identification was checked. Specimens were then dehydrated, gradually transferred from absolute alcohol into acetone (which is miscible with araldite) and stained with aceto-carmine before being embedded in a thin film of araldite on a glass slide. The araldite was cooked at 60°C for 24 hours until set and then cut to form a small cube around each specimen. A prepared capsule of araldite was trimmed to a

point at one end, the top cut off and a cube containing a specimen fixed to it with a drop of araldite. The capsule was baked as before until the araldite was set and the tip of the capsule was cut square close to the specimen. Ultra-thin sections were cut on a Porter Blum ultratome with a diamond knife and mounted on copper grids.

I am indebted to Dr. Celia Cave (Dept. of Botany & Microbiology, University College, London 1972) for advice on the preparation of specimens for transmission electron microscopy and for actually cutting the ultra-thin sections for me. The T.E.M. was operated by Graham Lawes of Birkbeck College, University of London.

CHAPTER 3. PALAEOBOTANICAL BACKGROUND.

3.1 SUMMARY OF PLANT MACROFOSSILS DESCRIBED FROM THE PALAEOCENE AND EARLY EOCENE OF SOUTHERN ENGLAND.

Plant remains were discovered from several Palaeocene and early Eocene horizons in Britain during the nineteenth century. These are well documented in the descriptions of contemporary excavations by Gardner (1883), Prestwich (1850, 1852, 1854), Webster (1814), Whitaker (1866, 1872, 1889) and Blake (in Monckton 1903). Some of these specimens were identified (or re-identified) and described by Hooker (1854, 1855), Gardner and Ettinghausen (1879, 1880, 1882), and Gardner (1880, 1883-1886).

The most comprehensive recent work is that of Reid & Chandler (1933) and Chandler (1961, 1964). They reassess some of the early identifications and describe much new material. Chandler (1964, p.2) comments that at least 140 genera and some 500 species (mainly fruits and seeds) have been described from the London Clay, although Collinson (1978) points out that many of these taxa are only known from single specimens. Table 3.1 (after Chandler 1961 and 1964) lists the taxa recovered from each of the Palaeocene formations and those which also occur in the London Clay and younger Palaeogene strata. For the complete floral list for the London Clay see Chandler 1961. Additional fruit, seeds and leaves from the London Clay are identified by Collinson (in George & Vincent 1977) and thirteen taxa are listed by Cooper (1977).

In contrast to the diversity of the London Clay material comparatively few taxa have been described from the Palaeocene horizons; Chandler (1964) lists only three species from the Thanet Beds (two species of *Pinus* and *Osmundites dowkeri* Carruthers); and about 24 species (fruits and seeds) from the Oldhaven Beds but these are generally poorly preserved. A few additional taxa have been recorded since; for example rare *Canticocculus* sp. and common seeds of *Iodes multireticulata* Reid & Chandler, from the *Astarte tenera* Bed in the Thanet Beds near Herne Bay (Ward 1978).

Chandler (1961, 1964) records about 40 species of fruits, seeds and leaves from the Woolwich and Reading

Table 3.1

TABLE 3.1

A. EXTANT GENERA RECOGNISED.

Family or section	Genus and species	Thanet Beds.	Woolwich & Reading Beds	Blackheath & Oldhaven Beds.	London Clay.	Younger strata
Equisetaceae	Equisetum sp. (2)		*			*
Osmundaceae	Osmunda dowkeri (Carruthers) Ch.	x				*
Schizaeaceae	Anemia subcretacea (Sa.) G. & Ett.		x		*	x
	Lygodium prestwichi (G. & Ett.) G.		x			
	Lygodium sp. (2)		*			
Pinaceae	Pinus macrocephalus (L. & H.) G.	x			*	*
	Pinus prestwichi G.	x				
	Pinus sp.		*			
Taxodineae	Sequoia couttsiae Heer.		x		x	x
	Sequoia sp.		*			
Cupressineae	Libocedrus adpressa G.		x		*	*
Betulaceae	Carpinus davisi Ch.		x			*
Menispermaceae	Cocculus? serratus (Ch.) Ch.			x	+	
	Tinospora excavata R. & Ch.			x	x	*
Hamamelidaceae	Liquidambar palaeocenica Ch.		x		+	
Rutaceae	Phellodendron costatum Ch.		x		+	x
	Zanthoxylon sp.			*		*
Icacinaceae	Natsiatum eocenicum Ch.		x	x	x	x
Vitaceae	Vitis sp. (3)			*	*	*
Theaceae	Cleyera? cooperi (Ch.) Ch.			x		
	Cleyera? stigmosa (Ludwig) Ch.		x	x	x	x
	Cleyera? warreni (Ch.) Ch.		x			
Flacourtiaceae	?Oncoba variabilis (Bowerbank) R. & Ch.		x		x	*
Haloragidaceae	Haloragis sp.		*		+	
Cornaceae	Mastixia sp.		*		*	*
Symplocaceae	?Symplocus sp.			*	*	*
Caprifoliaceae	Abelia palaeocenica Ch.		x			*
	Sambucus sp.		*			*

TABLE 3.1

B. ORGAN-GENERA RECOGNISED.

Family or section	Organ genus and species		Thanet Beds.	Woolwich & Reading Beds.	Blackheath & Oldhaven Beds.	London Clay.	Younger strata.
Cupressineae	Cupressistrobus gardneri Ch.			x		+	x
Potamogetonaceae	Limnocarpus cooperi Ch.				x	+	*
	Limnocarpus? magnus Ch.				x		
	Limnocarpus sp.				*		
Gramineae	Genus?			+			+
Cyperaceae	Caricoides obvata Ch.			x			*
	Caricoides minima (Ch.) Ch.			x			
Palmae	Genus?		+			+	+
Fagaceae	Quercinium porosum Brett.			x		+	*
Nymphaeaceae	?Palaeonymphaea sp. (=Carpolithes ovulum Brong.)			*		+	*
Menispermaceae	Canticocculus cooperi Ch.				x	+	+
	Genus?				+		
Lauraceae	Laurocarpum sp. (Cinnamomum sp.?)				*	*	*
	Laurocarpum spp. (5)			*			
	Laurocarpum spp. (2)				*		
Leguminosae	Leguminosites gardneri Ch.			x		+	+
	Leguminosites sp.			x			
	Genus? (Caesalpinoideae)			+			
Euphorbiaceae	Genus?				+	+	+
Anacardiaceae	Genus? (Rhus? or Pistacia?)			+		+	+
	Edenoxylon aemulum Brett (1966)			x			
Rhamnaceae	Genus?				+		+
Cornaceae	Eomastixia rugosa (Zenker) Ch.			x	?	+	x
Epacridaceae	Genus?				+	+	+
Apocynaceae	Apocynospermum lakense Ch.			?		+	x
	Genus?			+			
Cercidiphyllaceae	Jenkinsella apocynoides R & Rh.	preservation variants of the same organ (Crane 1978)		x		x	
	Carpolithes gardneri Ch.			x		*	*

KEY.

Taxa present	Abbreviations					
x - species	Brong.	-	Brongniart	H.	-	Hutton
* - genus	Ch.	-	Chandler	L.	-	Lindley
+ - family	Ett.	-	Ettinghausen	R.	-	Reid
	G.	-	Gardner	S.	-	Saporta

Beds, most specimens coming from comparatively few, restricted horizons. In the Reading area most are from the interval between the marine Bottom Bed and the mottled clays. Hooker (1854) describes fragmentary leaves from the Reading Leaf Bed, 10' (c.3m) above the Chalk in the railway cutting at Reading and Gardner (1886, p.400, quoted in Chandler 1961, p.68) reports leaf beds in Katesgrove Pit, in which one bed is almost wholly made up of leaves of Plantanus with fruits of the same common in the bed above. (Chandler 1964, p.68 refers these to the Hamamelidaceae; Liquidambar palaeocenica in part). Further specimens from the Reading Leaf Bed in the Waterloo Brickyard, Reading are described by Newton (in Monckton 1903) and are compared with Hooker's material. Chandler (1964, p.89) lists more material, nine different taxa, including leaves, fruits of Liquidambar palaeocenica and pods and twigs of Carpolithes gardneri which Chaloner collected from the Reading Leaf Bed at Waterloo Kiln in 1952. Further evidence of the abundance of plant material in the Reading Beds is given by Hawkins (1946), who describes a "peat of matted leaves" (c.2m above the Chalk) at Theale near Reading and a similar lignitic seam in a borehole in the Enborne Valley (1955) which he compares with one noted at Ewhurst, about 6·5km to the south, by Prestwich (1854).

Lignites have also been reported within the Woolwich facies of the Woolwich and Reading Beds from the central part of the London Basin, between London and Shorne Wood, Kent. Whitaker (1872) and Lavis (1876) mention a seam 3-6" (7.5-15cm) thick within the Plant Bed at Loam-Pit Hill, Lewisham and another occurs at St. Mary Cray (Whitaker 1872). The lignite seam below the Shell Beds at Shorne Wood, Kent, is well known from Chandler's description (1923) and from later excavations nearby (see Martin 1976). Other isolated occurrences are known from borehole data (e.g. the Crystal Palace Borehole see p. 32 above).

Most of the plant remains have come from the unit above the Shell Beds, the Striped Loams (i.e. the Plant Bed of Lavis (1876) and the Leaf Bed of Lewisham, Pitcher et al. (1967)). Many leaves and some seeds were found in this unit at Loam-Pit Hill (Lavis 1876). Also from Lewisham,

TABLE 3.2

TAXA RECORDED FROM COLD ASH QUARRY NEAR NEWBURY.

(after Crane 1977).

Cercidiphyllum leaf
Cercidiphyllum fruit (Carpolithes gardneri Ch.)
Cercidiphyllum seed
Carpinus winged fruit
Carpinus isolated nutlet
extinct Betulaceae, closely related to Carpinus and Corylus
Craspedromous leaf type (cf. Betulaceae)
Rhododendron seed
Rhamnospermum bilobatum Chandler
Pitted seed (cf. Vaccinium)
Leguminosites gardneri Chandler
Legume pods and leaflets (possibly Leguminoseae)
Spiny fruit (superficial similarity to Onobrychis)
Monocot. leaf fragments
Rhizome fragments (3 types).
Camptodromous leaf type (heterogeneous) serrate (probably Juglandaceae)
Camptodromous entire leaf type, Lauraceaephyllum stenolobatus (Lauraceae).
"Aralia looziana" Sap. & Mar. = Platanus schimperi (Platanaceae).
"Acer" leaf type
Entire margined leaf type (heterogeneous, few characters)
Conifer leafy shoot (small scraps only).

At least 15 further taxa including 8 other reproductive structures, dicotyledonous leaves, megaspores (Mineri-sporites spp., Horstisporites spp.) and fungi.

Hooker (1855) describes the seeds Carpolithes ovulum Brong., later referred to Palaeonymphaea sp. by Chandler (1961). Seed vessels and monocotyledonous and dicotyledonous leaves were found in the Woolwich Beds at Counter Hill near Lewisham (Prestwich 1854) including Asplenium (later referred to Pteris (?) prestwichii by Gardner & Ettinghausen (1879) and then to Lygodium prestwichii (G. & Ett.) Gardner). Other specimens recorded from the Woolwich Ballast Pit include Carpolithes? (in Prestwich 1854) and Whitaker (1889) lists taxa identified by Gardner from several localities, particularly Libocedrus adpressa Gardner from the Leaf Bed at Widmore, Bromley; Liriodendron gardneri Sap. from Dulwich and Lygodium prestwichii (Gard. & Ett.) Gardner from Lewisham, Croydon and Dulwich.

The most interesting recent finds of plant fossils come from Cold Ash Quarry near Newbury, from a series of clay and silt pockets within the cross-bedded sand unit near the base of the Reading Beds. The rich and diverse assemblages are particularly important because of their high proportion of angiosperm leaves as well as fruits and seeds. Mr. Peter Crane is currently investigating this material. Various fruits and seeds have already been described including Rhododendron seeds (Collinson & Crane 1978), fruit and leaves of the Ceridiphyllaceae, winged fruits of the Carpinus type, putative Leguminous pods, Leguminosites gardneri Chandler and various angiosperm leaves (Crane 1978). Collinson (1978) recognises dispersed anthers and seeds tentatively referable to Vaccinium and Cleyera.

Table 3.2 is taken from a field trip handout prepared by Mr. P. Crane (October 1977) and summarises the taxa he had recorded from Cold Ash Quarry at that time. The Cercidiphyllum types are considered to belong to an extinct genus similar to modern Cercidiphyllum, similarly the Carpinus winged fruit and isolated nutlets are believed to be extinct Betulaceae, closely related to Carpinus and Corylus. The legume pods are possibly Leguminoseae and are associated with related leaflets. The camptodromous entire leaf type is referred to Lauraceaephyllum stenolobatus and "Aralia looziana" Sap. & Mar. is in fact Platanus schimperi (Crane personal communication).

Comparison of macro- and microfloras from the London Clay (Ma Khin Sein 1961, Chandler 1961) has shown that the same taxa are not necessarily present or equally represented in the macro- and microfloras. The macrofossil finds from Cold Ash Quarry are therefore particularly relevant to the present study; although only two palynological samples have been examined the results complement the macrofossil data and help to give a more complete inventory of the Reading Beds flora as a whole (Chapter 5).

3.2 SUMMARY OF PREVIOUS PALAEOCENE AND EARLY EOCENE PALYNOLOGICAL STUDIES IN BRITAIN, NORTHWEST EUROPE AND NORTH AMERICA.

Pollen and spore assemblages from the Tertiary of northwest Europe are well known from the pioneering work of Potonié (1931, 1934), Potonié & Venitz (1934) and from the works of Thomson, Pflug, and Krutzsch during the 1950s (including Thomson & Pflug 1953, Pflug 1953, Krutzsch 1958). Many of the taxa they describe are long-ranging and are important constituents of the Palaeocene and early Eocene microfloras of southern England. Other significant additions to the early Tertiary microfloras of Europe have been made by Kedves (many papers on Hungary and the Paris Basin, particularly 1960, 1961, 1969, 1970, 1974); Gruas-Cavagnetto mainly on the Paris Basin (1966, 1967a, b, 1968, 1977) and Roche on Belgium (1965, 1968, 1973a, and b and, with Schumacker-Lambry, 1973). Krutzsch has continued to publish taxonomic and stratigraphic data (1962a, 1966, in Góczán et al. 1967, 1968, 1970 and, with Vanhoorne, 1977).

Similarly, many of the acid resistant microplankton taxa reported from early Tertiary sediments on the Continent also occur in southern England (see Pastiels 1948, Klumpp 1953, Alberti 1959, 1961, Morgenroth 1966, De Coninck 1969, 1971, Gocht 1969 and Caro 1973).

Figures 3.1 and 3.2 summarise the publications (mainly on pollen and spores but with a few on acid resistant microplankton) which are relevant to the present investigation. Data from Britain, northwest Europe and north America are included.

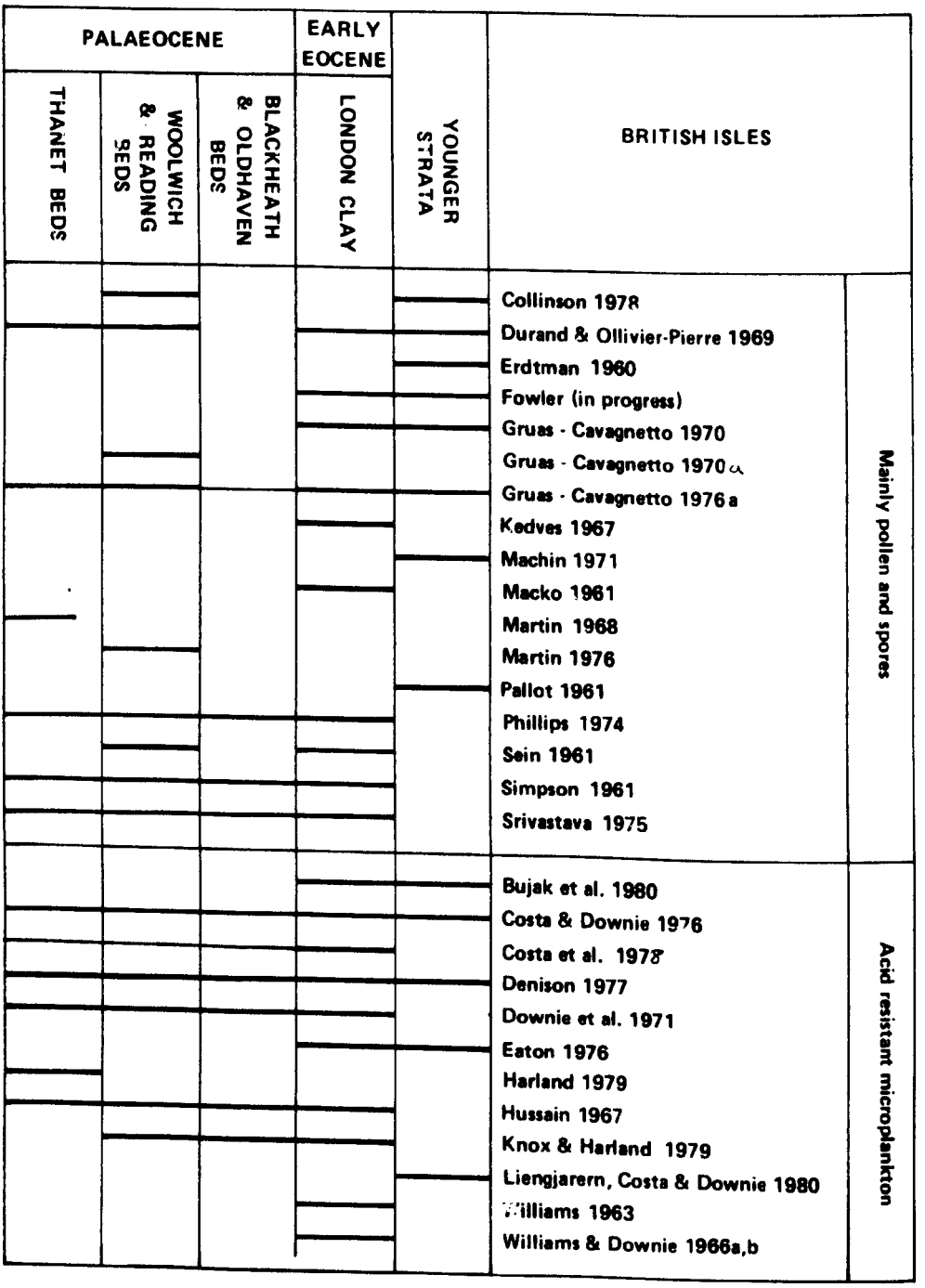
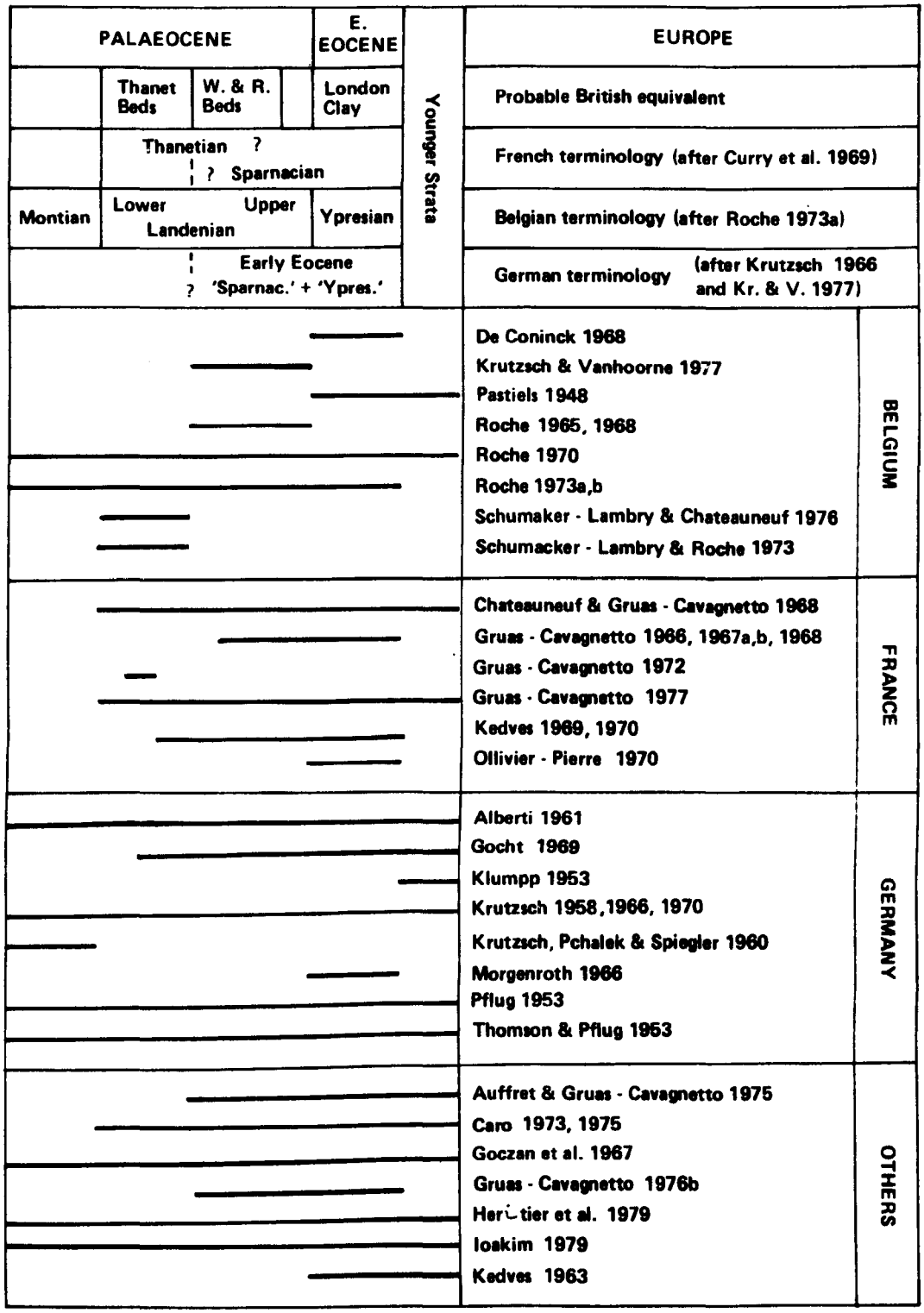


Figure 3.1 A selection from the palynological literature on Palaeocene and early Eocene deposits of Britain and other parts of northwest Europe.


PALAEOCENE
E. EOCENE
Younger Strata
EUROPE
Thanet Beds
W. & R. Beds
London Clay
Probable British equivalent
Thanetian ?
? Sparnacian
French terminology (after Curry et al. 1969)
Montian
Lower
Upper
Landenian
Ypresian
Belgian terminology (after Roche 1973a)
Early Eocene
? 'Sparnac.' + 'Ypres.'
German terminology (after Krutzsch 1966 and Kr. & V. 1977)
De Coninck 1968
Krutzsch & Vanhoorne 1977
Pastiels 1948
Roche 1965, 1968
Roche 1970
Roche 1973a,b
Schumaker - Lambry & Chateauneuf 1976
Schumacker - Lambry & Roche 1973
BELGIUM
Chateauneuf & Gruas - Cavagnetto 1968
Gruas - Cavagnetto 1966, 1967a,b, 1968
Gruas - Cavagnetto 1972
Gruas - Cavagnetto 1977
Kedves 1969, 1970
Ollivier - Pierre 1970
FRANCE
Alberti 1961
Gocht 1969
Klumpp 1953
Krutzsch 1958,1966, 1970
Krutzsch, Pchalek & Spiegler 1960
Morgenroth 1966
Pflug 1953
Thomson & Pflug 1953
GERMANY
Auffret & Gruas - Cavagnetto 1975
Caro 1973, 1975
Goczan et al. 1967
Gruas - Cavagnetto 1976b
Herbier et al. 1979
Ioakim 1979
Kedves 1963
OTHERS

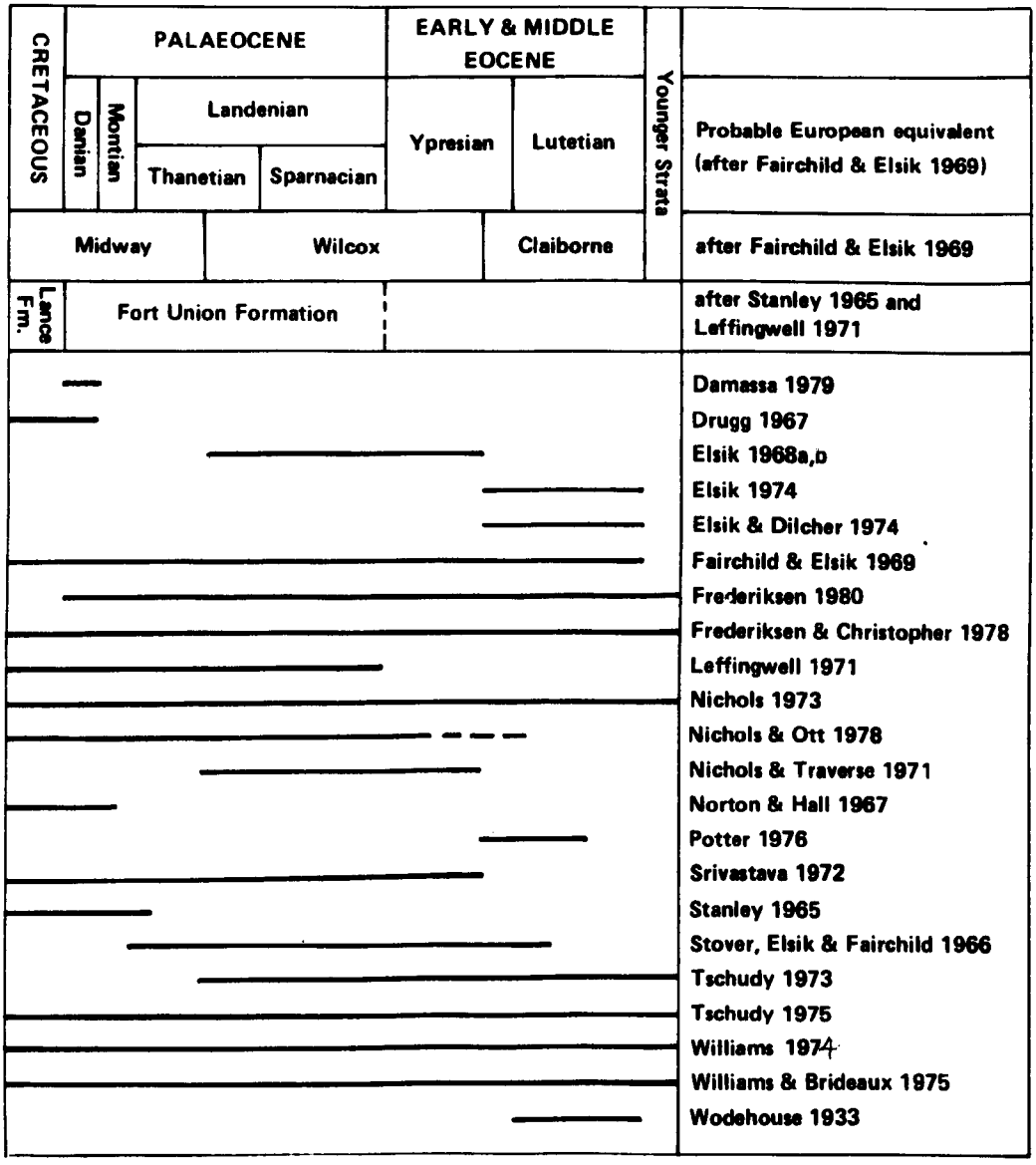


Figure 3.2 A selection from the palynological literature on Palaeocene and early Eocene deposits of North America.

There have been comparatively few publications dealing with pollen and spore assemblages of Palaeocene and early Eocene age from Britain. Amongst the earliest work is that of Simpson (published posthumously in 1961) which describes material from the Tertiary Igneous Province, from inter-basaltic sediments of Mull and adjacent areas. Although Simpson considers this assemblage to be Oligocene-Miocene in age, later workers disagree. Martin (1968) describes several species of the late Campanian-Danian genus Aquila-pollenites from these deposits and Phillips (1974) recognises assemblages dominated by reworked material. The deposits were also studied by Srivastava (1975). He concludes that they are of Maastrichtian age although Boulter (in Curry et al. 1978) questions this interpretation and favours a Palaeocene-Eocene age.

Several palynological studies of early Tertiary sediments from southern England are predominantly taxonomic. Macko (1961) and Sein (1961) describe taxa present in the London Clay although the latter also includes some information about the Woolwich and Reading Beds. Ma Khin Sein compares the fossil taxa with pollen from extant genera and, from their present ecological requirements, she extrapolates the possible climatic conditions which prevailed in southern England during the deposition of the London Clay. Pallot's study (1961) also compares fossil and extant taxa and she considers the ecological implications for the fossil microflora. Although her material (Eocene-Oligocene) is considerably younger than mine her assemblages are useful for comparison and for establishing the upper limit of some of the taxa found in the Palaeocene and early Eocene. Durand & Ollivier-Pierre (1969) briefly examined the Thanet Beds, Woolwich and Reading Beds and London Clay, as well as younger formations, in their search for fossil Nipa pollen, although they only record it from horizons above the London Clay.

Publications which are of direct relevance to the present investigation include Gruas-Cavagnetto (1970a), in which a microflora from the Woolwich and Reading Beds at the Swanscombe Park road cutting is described. In her 1976a

paper Gruas-Cavagnetto summarises the stratigraphical distribution of taxa obtained from British sections and gives the results of pollen counts on samples from the Thanet Beds (5), the Woolwich and Reading Beds (5, including two of my samples, from the Lignite and the Woolwich Shell Beds at Shorne Wood) and the London Clay (4), as well as from younger strata. Martin (1976) describes megaspore and microspore massulae of Azolla anglica Martin and Salvinia cobhamii Martin from the lignite within the Woolwich and Reading Beds at Shorne Wood and presents a pollen diagram based on four samples through the lignite (see discussion Chapter 5.3).

As part of her study of plant macrofossils from southern England Collinson (1978) gives results of palynological analyses of samples from the Reading Beds from Cold Ash Quarry near Newbury and compares the microflora with the plant macrofossils recorded from the same site (Collinson & Crane 1978, Crane 1978). Dr. K. Fowler is currently studying spores and pollen from Eocene to Oligocene sediments of the Hampshire Basin, including the higher parts of the London Clay at Alum and Whitecliff Bays.

Since the early 1960s several theses have been written on acid resistant microplankton from Palaeocene and early Eocene strata of southern England. Hussain (1967) records assemblages from the Thanet Beds to the London Clay and Williams also describes dinoflagellate cysts from the London Clay (1963 and in Davey et al. 1966). Data from both of these works are summarised in Downie, Hussain and Williams (1971) in which a series of microplankton associations is described. Denison (1977) also defines dinoflagellate cyst associations from the Thanet Beds to London Clay and compares these with microfloras described from northwest Europe.

Several dinoflagellate cyst zones and associations have been recognised through the early Tertiary in northwest Europe. The Deflandrea speciosa Zone in the Ilerdian of Spain (in part equivalent to the late Palaeocene) was established by Caro (1973) but the zonal index species was not recognised in the British succession until Harland (in Knox and Harland 1979) suggested that D. speciosa and D. oebisfeldensis were synonymous. The latter is present in

the Thanet Beds (Denison 1977, Harland 1979 and personal observation). Hussain (1967), Downie, Hussain and Willians (1971) and Denison (1977) record a distinctive Areoligera association in the Thanet Beds of the London Basin. Hussain also recognises a new species of Eisenackia which occurs commonly at that level although rare specimens do occur in the London Clay. This form is also described by Denison (as Eisenackia minima, 1977) and was published as Alisocysta margarita by Harland (1979) who considers it to be a useful Thanetian marker. It appears to have a widespread distribution since Caro illustrates a specimen from Spain (1973), Drugg (1967) and Damassa (1979 , as Alisocysta rugolirata) record it in the Danian of California and it occurs in the late Palaeocene of the North Sea (Harland 1979, Ioakim 1979, personal observation).

The Woolwich facies of the Woolwich and Reading Beds contains assemblages characterised by species of Apectodinium (formerly Wetzeliella). These are the Wetzeliella associations of Hussain (1967), Downie et al. (1971) and Denison (1977). Costa & Downie (1976) use various species of Wetzeliella (a taxon now revised to include Apectodinium, Kisselovia and Rhombodinium) to establish a series of eight zones, ranging in age from late Palaeocene to Oligocene and recognisable in France, Belgium and Germany as well as in Britain. These, and other Wetzeliella Zones are also recognised in southern England by Denison (1977) and Costa, Denison and Downie (1978), in the English Channel (Auffret & Graus-Cavegnetto 1975 and Gruas-Cavagnetto 1976b), in the North Sea (Héritier, Lossel & Wathne 1979, Ioakim 1979 and Knox and Harland 1979) and in Spain and southern France (Caro 1973).

In contrast, Eaton (1976) bases his zonal scheme for Eocene strata of the Isle of Wight on a variety of different genera and incorporates Williams's data to cover the London Clay sequences at the base of his sections. Although Eaton's material is younger than mine his data are useful for demonstrating the upper limits of some of the Palaeocene and early Eocene taxa. In their 1980 publication Bujak, Downie,Eaton and Williams combine their data to produce a zonation based on dinoflagellate cysts from the

London Clay to the Barton Beds (early Eocene to Oligocene).

A considerable volume of work, both on pollen and spores and on acid resistant microplankton is available on early Tertiary sections from North America. A small selection of papers is listed in Figure 3.2.

One difficulty in comparing north American and European pollen assemblages arises from the practice, favoured by some American authors, of assigning fossil spores and pollen to recent genera (Stanley 1965, Elsik 1974). Most European workers in contrast generally use form-generic names (Thomson and Pflug 1953, Kedves 1960 and others, Krutzsch 1961, Roche 1965 etc. and Gruas-Cavagnetto 1968), although, in her most recent works Gruas-Cavagnetto does place greater emphasis on the probable botanical affinities of the fossils (e.g. 1976a, 1977).

Elsik's descriptions of pollen and spores from the Palaeocene of Texas (1968a, b) are of direct relevance to the current investigation, as are the discussion of assemblages from Palaeocene-Eocene lignites from different depositional environments (Nicols and Traverse 1971) and the taxonomic studies of small triatriate pollen (Nichols 1973, Frederiksen and Christopher 1978, Nichols and Ott 1978). The work of Tschudy (1973a), Elsik (1974) and Elsik and Dilcher (1974) suggests that the stratigraphic ranges of several taxa in North America differ slightly from their European equivalents.

The papers of Stanley (1965) and Drugg (1967) include dinoflagellate cysts as well as pollen and spores. Other publications useful for comparison with the British dinoflagellate assemblages include several papers on Canadian sections by Williams (1974 and later), and Williams and Brideaux (1975).

CHAPTER 4. SYSTEMATIC SECTION

This chapter is divided into two parts. The first deals primarily with spores and pollen but also includes very brief comments on the few seeds and fruits found in the Woolwich and Reading Beds; and the second part deals with the acid resistant microplankton, dinoflagellate cysts, acritarchs and other algae.

Selected species are illustrated on plates 1-24.

4.1 SPORES AND POLLEN

Nomenclature and Classification

There is no general agreement amongst Tertiary palynologists as to whether form-genera or extant genera are the most appropriate for dispersed Tertiary pollen. Some authors have used only fossil names and have based their supra-generic classification on morphology (Thomson & Pflug 1953, Potonié, 1956, 1960, 1966, Elsik 1968); others have used form-genera but have attempted to determine the botanical affinity of the fossil pollen and have used a natural (botanical) supra-generic classification, placing the genera into appropriate extant families (Gruas-Cavagnetto 1968, 1977); yet others have placed the fossil pollen into extant genera whenever possible (Traverse 1955, Fairchild & Elsik 1969) or have used a mixture of extant and fossil genera (Stanley 1965, Tschudy 1973, Frederiksen 1979, 1980). On the whole workers in northwest Europe have tended to use form-genera and to follow the morphographic classification of Potonié (1956 *et. seq.*) while North American workers have more frequently placed fossil material into extant genera.

There are several arguments against using extant genera for dispersed fossil pollen. From the botanical point of view there is usually insufficient evidence to prove that the whole fossil plant closely resembles the extant genus even though the fossil pollen is remarkably similar (e.g. *Platycarya*, *Alnus*, *Nyssa*). The pollen of many recent genera has not yet been studied and so is not available for comparison with fossil material. In every fossil assemblage

of dispersed pollen very few forms are distinct enough to be compared directly with extant genera, another type of nomenclature is therefore needed for the remainder, the major part of the assemblage.

Most of the pollen types found in southern England have already been described under form-genera in the literature from northwest Europe. In order to facilitate comparison between these microfloras and those recovered from southern England I also have used form-genera and the morphographic classification of Potonié (1956 et. seq.). I have tried to follow the International Code of Botanical Nomenclature, Leningrad 1975 (Stafleu et al. 1978) as far as is practicable. In addition, the botanical affinity is also given for each species described wherever this is known.

Descriptions. Since most of the species I have found in southern England have already been described in the literature only selected taxa are dealt with in detail. All remaining taxa are listed, some with an illustration and some with a short list of published illustrations which I consider to be typical of the taxon.

All identifications and synonomy lists are based solely on the examination of illustrations, no type material has been examined.

The groups considered in some detail include:

i) genera in which species show considerable morphological variation and inter-gradation (e.g. Sparganiaceae-pollenites);

ii) certain morphological groups in which the differentiation of genera or species is controversial (e.g. the Momipites Group);

iii) species which I have studied with the scanning or transmission electron microscope (e.g. Pistillipollenites mcgregorii).

iv) species which have only been recorded rarely in the literature;

v) new species.

These forms are described and/or compared with similar species; the dimensions are given for specimens from southern England (based on 10 specimens unless stated

otherwise); the botanical affinity is noted; general comments are made on the distribution in southern England (Observed distribution) and the distribution as previously reported in the literature (Reported distribution) is summarised. Further details of the distribution of individual taxa in southern England are shown in Appendix 2.

New species.

Several of the species described below are recognised as new. However, since species created in a thesis do not fulfil the criteria necessary for effective publication (I.C.B.N. 1978, Art. 29, 32) these are treated informally here. Each is placed in the appropriate genus as "species A" etc., specific epithets will be chosen before publication. For each species one "typical specimen" has been chosen instead of a holotype. Descriptions are based on a minimum of five specimens, more where they are available.

Terminology.

Most of the descriptive terms I have used are defined in the "Morphologic Encyclopedia of Palynology" (Kremp 1965). Those listed below have a variety of definitions, my usage is as follows:

Ektexine/endexine: I have followed Faegri & Iversen 1950, p.16. (see Kremp 1965, p.44) "where the exine is more complex, it is possible to distinguish between two layers, an inner and an outer, which are called, respectively endexine and ektexine. The inner layer forms a continuous homogenous membrane" Measurements of endexine and ektexine given in the descriptions below refer to these two layers.

Foot layer of the ektexine: In some of my specimens, however, two distinct layers are visible within the homogenous endexine; the outer one probably corresponds to the foot layer (i.e. the basal, non-sculptured portion of the ektexine) and the inner one to the more restricted "endexine" in the terminology of Larson, Skvarla & Lewis, 1962 (Kremp 1965, p.156 and fig.545).

Tectum Erdtman 1952, p.19 see Kremp 1965, p.166 and fig.648; equivalent to tegillum Erdtman 1952, p.471 "an

ectosexinous, ± homogenous layer usually distinctly separated from the nexine by a baculate zone "(endosexine)" (Kremp 1965, p.166).

Costa (plural costae): Traverse 1955, p.95 (see Kremp 1965, p.32) "Endexinous thickenings under the rims of furrows or germpores".

Margo (plural margines): Traverse 1955, p.93. "A narrow zone bordering a furrow. The margo is different from normal exine in ektexinous features, either in sculpture, and/or thickness. The ektexine is usually thinner in the margo than in normal exine, but may be thicker".

Ornament: I use this term in the same way that Faegri & Iversen use "sculpture" (1950, p.25-27, see Kremp 1965, p.100). "Sculpturing elements; those elements which project beyond an imaginary even surface, either the endexine in intectate pollen or an imaginary surface touching the lowermost parts of the tectum". Equivalent to Potonie & Kremp 1955 (in Kremp 1965, p.105) "Sculpture - Only those form elements which stand out in relief on the surface of the exine can be called sculpture".

Scabrate: "flecked; with minute pits or elevations less than 1 micron in size" (Couper 1958, see Kremp 1965, p.106).

Simplibaculate/duplibaculate/multibaculate: Erdtman 1952. "muri etc., supported by a single row of bacula are simplibaculate". (Erdtman 1952, p.459 and Kremp 1965, p.141, fig.s 724, 725). The bacula in fig.725 are the supporting rods of the clavae. Similarly duplibaculate refers to two rows of supporting bacula (Erdt. 1952, p.462 and Kremp 1965, p.41, fig.720) and multibaculate refers to more than two rows of bacula (Erdt. 1952, p.465 and Kremp 1965, p.92).

Structure: "In tectate pollen grains one can differentiate in analogy to pollen sculpture types the following structure types according to the distribution of granulae beneath the tectum" (Iversen & Troels-Smith 1950, see Kremp 1965, p.102). Equivalent to Erdtman 1943, p.52 "structure, texture; different patterns in surface view usually more or less 'granular', not produced by eventual sculpturing of the exine but by formative elements within the exine" (see Kremp 1965, p.159).

Ruga (plural rugae): Thomson & Pflug 1953, p.20, translation from Kremp 1965, p.134 " . . . colpi of appropriate structure which stretch parallel to the equator".

ANTETURMA: SPORITES H. Potonié 1893.
TURMA: TRILETES Reinsch emend. Dettmann 1963
SUBTURMA: AZONOTRILETES Luber emend. Dettmann 1963
INFRATURMA: LAEVIGATI Bennie & Kidston emend. Potonié 1956

Genus: HYDROSPORIS Krutzsch 1962
Type species: H. azollaensis W. Kr. 1962
Hydrosporis levis W. Kr. 1962
Plate 1, figs. 1,2.

1976 Salvinia cobhamii Martin, pl.28, fig.5.
1977 Hydrosporis levis W. Kr. 1962; W. Kr. & Vanhoorne, p.8, pl.3, fig.9-11, pl.9, fig.10-11.

Comments. Microspore massulae, without visible glochidia (plate 1, fig. 4), occur in the lignite horizon in the Woolwich and Reading Beds at Shorne Wood (sample JL 865). Microspores are clearly visible within teased microspore massulae (plate 1, fig. 1,2) although no dispersed specimens were seen. They are small, trilete spores, generally rounded triangular to circular in shape with a smooth exine.
Size. 10 specimens, 17.5 (27.0) 32.0 microns.
Comparison. Martin (1976) describes microspore massulae and microspores of Salvinia cobhamii from this locality. His description and illustration of the microspores (pl.28, fig.5) and the massulae (pl.27, fig.7) appear identical with the material recorded in the present study. However, Martin comments that the classification of fossil Salvinia species depends on both the leaves and on the spore bodies and that there is little evidence that the microspore massulae are at all species-diagnostic (p.180). The present material is therefore placed in the most suitable species for dispersed spores.
Botanical affinity. Krutzsch & Vanhoorne (1977, p.9) relate

H. levis to Azolla or Salvinia. The similarity with Martin's material makes affinity with Salvinia more likely.
Observed distribution. Present only in the lignite sample JL 865 from the Woolwich and Reading Beds at Shorne Wood.
Reported distribution. See Krutzsch 1962a.

Genus: LEIOTRILETES (Naumova) Potonié & Kremp 1954
Type species: L. sphaerotriangulus (Loose) Pot. & Kemp 1954
Leiotriletes spp.
Plate 1, fig. 5,10.

Observed distribution. Large, smooth trilete spores of this general morphology occur fairly commonly in the lignitic horizon in the Woolwich and Reading Beds at Shorne Wood. Individual species have not been determined.

OTHER TAXA:
Dictyophyllidites harrisii Couper 1958
Stereisporites spp.
Triplanosporites sinuosus (Pflug 1952) Thomson & Pflug 1953.
See plate 1, fig. 3 and Roche 1973, pl.1, fig.20,21.

INFRATURMA: APICULATI Bennie & Kidston emend. Potonié 1956

Genus: TEGUMENTISPORIS Krutzsch 1963.
Type species. Trilites tegumentis Krutzsch 1959.
?Tegumentisporis sp.
Plate 1, fig. 7,8,11,12.

Comments. Tegumentisporis rugulus (W. Kr. 1959b) W. Kr. 1963 in Krutzsch & Vanhoorne (1977, p.13, pl.40, fig.7-10) is similar but probably not identical.
Observed distribution. Separate species have not been identified. The genus is never common but is most characteristic of the Reading facies of the Woolwich and Reading Beds at the western end of the London Basin, the Pincents Kiln and Cold Ash Quarry sections.

OTHER TAXA:
Baculatisporites comaumensis (Cookson 1955) Potonié 1956.
Concavissimisporites verrucosus Delcourt & Sprumont 1955 (reworked).
Leptolepidites spp. (reworked)

Osmundacidites wellmanii Couper 1953.

Pilosisporites trichopapillosus (Thiergart) Delcourt & Sprumont 1955 (reworked).

Trachysporites fuscus Nilsson 1958 (reworked).

Uvaesporites argenteaeformis (Bolchovitina) Schultz 1967 (reworked).

INFRATURMA: MURORNATI Potonié & Kremp 1954

Cicatricosisporites dorogensis Potonié & Gelletich 1933. See plate 1, fig. 14 and Krutzsch 1958, pl.1, fig. 22-25; Roche 1973, pl.2, fig.1-3.

Cicatricosisporites paradorogensis Krutzsch 1959. See plate 1, fig. 15 and Roche 1973, pl.2, fig.4-6; Krutzsch & Vanhoorne 1977, pl.7, fig.1, 2.

Cicatricosisporites spp.

Klukisporites spp. (reworked in part).

Lycopodiumsporites clavatoides Couper 1958 (reworked in part).

Lycopodiumsporites spp.

Taurocusporites segmentatus Stover 1962 (reworked).

SUBTURMA: ZONOTRILETES Waltz 1935

INFRATURMA: CINGULATI Potonié & Klaus emend. Dettmann 1963

Genus: POLYPODIACEOISPORITES Potonié 1956

Type species. Polypodiaceoisporites (al. Sporites) speciosus (R. Pot. 1934b) Potonie 1956.

Polypodiaceoisporites macrospeciosus (R. Pot. & Gell. 1933) Potonié 1956

Plate 1, fig. 16.

1961 Polypodiaceoisporites potoniei (R. Pot. & Gell.) Kedves subfsp. minor; Kedves p.136, pl.7, fig.22,23 only.

1965 Polypodiaceoisporites macrospeciosus (R. Pot.) Kedves 1961; Roche p.428, pl.1, fig.5,6,7.

1973 Polypodiaceoisporites potoniei Kedves 1961, subfsp. major Kedves 1961; Roche, p.40, pl.2, fig.17,18.

1977 Polypodiaceoisporites potoniei (R. Pot. & Gell. 1933)

Kds. 1961; Gr.-Cav. pl.2, fig.1,2.

Comments. The London Basin material is comparable to specimens of P. "potoniei" illustrated by Kedves (1961, see above). This species was not validly published however and Krutzsch (1967a) considers it to be a junior synonym of P. macrospeciosus.

Observed distribution. Rare but persistent in the Woolwich and Reading Beds. Not separated from other species of Polypodiaceoisporites in counts.

Polypodiaceoisporites marxheimensis (Murriger & Pflug 1952 ex Thomson & Pflug 1953) Krutzsch 1959b.

Plate 1, fig. 9.

1953 Cingulatisporites marxheimensis (Murr. & Pf. Th. & Pf. p.58, pl.1, fig.13-15.

Polypodiaceoisporites sp. cf. P. marxheimensis.

Plate 1, fig.6,13.

1968 Cingulatisporites cf. marxheimensis (Murr. & Pflug) Th. & Pf.; Nakoman, pl.2, fig.4,5.

1977 Polypodiaceoisporites marxheimensis (Murr. & Pflug. 1952 ex. Th. & Pf. 1953) W. Kr. 1959b; Krutzsch & Vanhoorne p.18, pl.8, fig.1-5.

Comments: Krutzsch & Vanhoorne (1977, p.18) consider their specimens to be symonymous with specimens illustrated by Thomson & Pflug (1953, pl.1, fig.13-15), reproductions of Murriger & Pflug's original material. The ornament differs however; the type species has verrucate rather than rugulate distal ornament. The rugulate ornament is clear in both Nakoman's and Krutzsch & Vanhoorne's illustrations and also in the London Basin material.

Botanical affinity. Kedves (1967, p.542, 544) notes that the botanical affinity of the genus is difficult to establish but considers that affinity with Pteris is the most likely.

Observed distribution. Separate species have not generally been distinguished in counts. The genus occurs irregularly

in the Woolwich and Reading Beds and London Clay but is never common.

Reported distribution. Genus; Sparnacian to Bartonian (Palaeocene -late Eocene, Kedves 1963); Oligocene-Miocene (Thomson & Pflug 1953), Palaeocene (Krutzsch & Vanhoorne 1977).

OTHER TAXA:

Contignisporites problematicus (Couper 1958) Döring 1965 (reworked).

Densosporites sp. (reworked).

Kraeuselisporites reissingeri (Harris 1957) Morbey 1975 (reworked). See plate 1, fig. 19 and Orbell 1973 (as Heliosporites reissingeri) pl.3, fig.14; Morbey 1975, pl.9, fig.10-13.

Limbosporites lundbladi Nilsson 1958 (reworked)

Lycospora sp. (reworked).

INFRATURMA: AURICULATI Schopf emend. Dettmann 1963

Appendicisporites spp. (reworked).

Ischyosporites spp. (reworked).

Trilobosporites spp. (reworked).

Triquitrites spp. (reworked).

INFRATURMA: TRICRASSATI Dettmann 1964

Camarozonosporites sp.

Coronatispora valdensis (Couper 1958) Dettmann 1963 (reworked).

Gleicheniidites senonicus Ross 1949 ex Decourt & Sprumont 1955 (reworked in part).

SUPRASUBTURMA: PERINOTRILETES Erdtman 1948 emend. Dettmann 1963

Genus: DENSOISPORITES Weyland & Krieger 1953 emend. Dettmann 1963

Type species: D. velatus Weyland & Krieger 1953

Densoisporites velatus Weyland & Krieger 1953 Plate 1, fig. 17,18.

1958 Densoisporites perinatus Couper, p.145, pl.23;

fig. 6-9.

1963 Densoisporites velatus Weyland & Krieger; Dettmann p.84, pl.19, fig.4-6.

Comments. Specimens from the London Basin compare well with Couper's and Dettmann's illustrations and may be reworked. However, Miocene specimens of Lusatisporis cf. perinatus shown in Krutzsch 1963 (pl.30, fig. 10,11) and of cf. Lusatisporis Krutzsch 1963, in Sontag (1966, pl.5, fig. 1c,1d) are also very similar. It is possible therefore, that some of the specimens included here may be in place Tertiary specimens rather than reworked Mesozoic material.

TURMA: MONOLETES Ibrahim 1933
SUBTURMA: AZONOMONOLETES Luber 1935
INFRATURMA: LAEVIGATOMONOLETES Ibrahim 1933
Genus: LAEVIGATOSPORITES Ibrahim 1933
Type species: L. vulgaris Ibrahim 1933

Laevigatosporites discordatus Pflug 1953

Plate 2, fig.1.

1953 Laevigatosporites discordatus Pf., in Th. & Pf., p.59, pl.3, fig.39-44.

Comments. Distinguished from Laevigatosporites haardti by its larger size and its more spherical shape.
Botanical affinity. Polypodiaceae (Gruas-Cavagnetto 1968).
Observed distribution. Fairly common in the lignite in the Woolwich and Reading Beds, otherwise rare.
Reported distribution. ?Danian-middle Oligocene (Thomson & Pflug 1953), Palaeocene of Belgium (Roche 1965, Krutzsch & Vanhoorne 1977).

Laevigatosporites haardti (R. Pot. & Venitz 1934) Thomson & Pflug 1953.

Plate 2, fig. 3.

1953 Laevigatosporites haardti (Pot. & Ven.) Th. & Pf., p.59, pl.3, fig.27-28.

Botanical affinity. Polypodiaceae (Gruas-Cavagnetto 1968). Observed distribution. Common in the lignite horizon of the Woolwich and Reading Beds (JL 867); sporadic elsewhere. Reported distribution. Known throughout the Tertiary, Danian-Pliocene (Thomson & Pflug 1953), Palaeocene of Belgium (Roche 1965, Krutzsch & Vanhoorne 1977).

INFRATURMA: SCULPTATOMONOLETI Dybová & Jachowicz 1957

Verrucatosporites favus (Potonié) Pflug & Thomson 1953. Ornamented spores, undifferentiated. See plate 2, fig. 2.

TURMA: HILATES Dettmann 1963

Aequitriradites spp. (reworked).

ANTETURMA: POLLENITES Potonié 1931

TURMA: SACCITES Erdtman 1947

SUBTURMA: MONOSACCITES Chitaley emend. Potonié & Kremp 1954

INFRATURMA: ARADIATES Bharadwaj 1957a

Florinites sp. (reworked) See plate 2, fig.11.

INFRATURMA: ALETISACCITI

Perinopollenites elatoides Couper 1958 (?reworked).

INFRATURMA: SACCIZONATI Bharadwaj 1957

Callialasporites dampieri (Balme) Sukh Dev 1961 (reworked) See plate 2, fig.5.

Callialasporites trilobatus (Balme) Sukh Dev 1961 (reworked)

Cerebropollenites mesozoicus (Couper 1958) Nilsson 1958 (reworked). See plate 2, fig.4 and Norris, 1969, pl.109, fig.11,12.

Inaperturopollenites turbatus Balme 1957 (reworked)

SUBTURMA: DISACCITES Cookson 1947

Alisporites microsaccus Couper 1958 (reworked).

Parvisaccites radiatus Couper 1958 (reworked).

Podocarpidites sp. (?reworked).

Quadraeculina anellaeformis Maljavkina 1949 sensu Schulz 1967 (reworked). See plate 2, fig.8 and Orbell 1973, pl.3, fig.15.

Vitreisporites pallidus (Reissinger) Nilsson 1958 (reworked) See plate 2, fig.10.

Bisaccate pollen, undifferentiated. See plate 2, fig.6,7.

SUBTURMA: STRIATITES Pant 1954

Taeniaesporites sp. cf. T. noviaulensis Leschik 1955 (reworked) See plate 2, fig.9.

TURMA: ALETES Ibrahim 1933 and KRYPTAPERTURATES Potonié 1966

SUBTURMA: AZONALETES Luber emend. Potonié & Kremp 1954

Araucariacites australis Cookson 1947 (?reworked).

Inaperturopollenites dubius (Potonié) Pflug & Thomson 1953.

Inaperturopollenites hiatus (Potonié) Pflug & Thomson 1953. See plate 2, fig.18 and Thomson & Pflug pl.5, fig.14-20.

Inaperturopollenites polyformosus (Thiergart) Pflug & Thomson 1953. See plate 2, fig.13,14 and Thomson & Pflug pl.5, fig.21-25.

Spheripollenites scabratus Couper 1958. See plate 2, fig.16,17 and Couper 1958, pl.31, fig.12,13. Comments. Although this genus is defined as being monoporate none of the specimens I have seen have a true pore, merely a small thin area over the pole, often very indistinct and not always present. Small spherical pollen, comparable to Spheripollenites scabratus Couper 1958, occur at most horizons examined. Some specimens are probably reworked, particularly those associated with Classopollis torosus and other Mesozoic forms, others however have similar preservation to the Tertiary species and may be in place.

INFRATURMA: CIRCUMPOLLINI Pflug 1953 emend. Klaus 1960

Classopollis echinatus Burger 1965 (reworked).

Classopollis torosus (Reissinger) Balme 1957 (reworked). See plate 2, fig.15 and Orbell 1973, pl.1, fig.7.

Corollina meyeriana (Klaus) Venkatachala & Góczán 1964 (reworked).

Granuloperculatipollis rudis Venkatachala & Góczán 1964 (reworked).

Rhaetipollis germanicus Schulz 1967 (reworked). See plate 2, fig.19 and Orbell 1973, pl.2, fig.3; Morbey & Dunay 1978, pl.4, fig.7.

TURMA: PLICATES Naumova 1937, 1939 emend. Potonié 1960

SUBTURMA: PRAECOLPATES Potonié & Kremp 1954

Eucommiidites minor Groot & Penny 1960 (reworked)

Eucommiidites troedssonii Erdtman 1948 (reworked).

SUBTURMA: MONOCOLPATES Iversen & Troels-Smith 1950.

Genus: MILFORDIA Erdtman 1960

Type species: Milfordia incerta subsp. incerta (Th. & Pf. 1953) Krutzsch 1961d; pl.5, fig.34 Th. & Pf. 1953 (as Inaperturopollenites incertus subsp. foveolatus).

Milfordia incerta (Th. & Pf. 1953) Krutzsch 1961d
Plate 3, fig.1.

1953 Inaperturopollenites incertus Pf. & Th. subsp. foveolatus p.66, pl.5, fig.34 only.
1958 incertus Gruppe; W.Kr. p.521, pl.10, fig.41,42,43.
1960 "Inaperturopollenites" incertus Th. & Pf.; W.Kr. in W.Kr., Pchalek & Spiegler, pl.2, fig.11.
1960 Milfordia hypolaenoides Erdt., pl.1a, p.46.
1961 Restio sp. A. Ma Khin Sein, p.131, pl.8, fig.71,72.
1970c Milfordia incerta (Th. & Pf. 1953) W.Kr. 1961d; W.Kr. p.72,74, pl.9, fig.s1-26.
1971 Centrolepis sp. Machin, pl.2, fig.13.
1976 Milfordia incerta (Th. & Pf. 1953) W.Kr.; W.Kr. & Vanh. p.24, pl.11, fig.16.

Size. 29.0 (37.5) 48.0 microns. 7 specimens.

Comparison. The genus is distinguished from the monoporate, foveolate genus Restioniidites Elsik 1968 by the presence of a colpus with jagged margins, surrounded by easily detachable exine fragments.

Botanical affinity. Erdtman (1960, p.46,47) considers the jagged margin of the colpus, surrounded by easily detachable exine fragments as characteristic of some recent restionaceous plants, including Hypolaena lateriflora, and he refers Milfordia to the Restionaceae or Centrolepidaceae. Ladd (1977) illustrates the pollen of several other extant species from genera within the Restionaceae and Centrolepidaceae which have similar general morphology and particularly similar apertures (centrolepidoid, surrounded by loose exine fragments) e.g. Calorophus lateriflorus, fig.1 and Restio stenostachyus, fig.16.

Observed distribution. Rare. Present in the Thanet Beds, Woolwich and Reading Beds, London Clay and Bracklesham Beds.

Recorded distribution. Krutzsch (1970a, p.325) gives the first occurrence of this form in Central Europe as Middle

to Upper Danian; it has general distribution by the Eocene, is more sparse by the Upper Oligocene but isolated examples do occur up to the Middle Miocene.

Genus: SPINIZONOCOLPITES Muller 1968
Type species: Spinizonocolpites echinatus Muller 1968, p.11, pl.3, fig.3.

Spinizonocolpites echinatus Muller 1968.
Plate 3, fig. 2,3.

1968 Spinizonocolpites echinatus Muller, p.11, pl.3, fig.3.
1968 Spinizonocolpites baculatus Muller, p.11, pl.3, fig.2.
1968 Spinizonocolpites baculatus Muller; Germ., H.& Muller pl.4, fig.2.
1968 Spinizonocolpites echinatus Muller; Germ., H. & Muller, pl.4, fig.3.
1969 Spinizonocolpites baculatus Muller; Durand & O. - Pierre, p.51, pl.3, fig.3.
1976a Spinizonocolpites baculatus Muller; Gr.-Cav. pl.3, fig.12,13.

Comments. Although Muller (1968, p.11) separates S. echinatus from S. baculatus on the shape of the spines and on the larger size and coarser wall structure of S. baculatus, he states that transitional forms do occur. Other authors have recognised the difficulties of separating the two species particularly Germeraad, Hopping and Muller (1968) who group both species together and Durand & Ollivier-Pierre (1969, p.51) who record transitional forms. All specimens recorded in the present study have been placed in S. echinatus.

Botanical affinity. Complete specimens, in which two hemispheres are preserved, are probably related to the palm Nipa. Where there is only one "hemisphere" the specimen could be interpreted as a monocolpate pollen grain (rather than zono-colpate) and affinity with Nuphar or Nymphaceae is possible (Collinson, personal communication 1980).

Observed distribution. Rare. Only recorded from Alum Bay, samples AB54, AB58 i.e. London Clay, Divisions B-D of King 1981; in the Bracklesham Beds AB57,AB60, AB63 and AB64 (Beds 1 and 2 of Eaton), AB68 (roughly equivalent to Fisher's Bed IV) and AB70 (roughly equivalent to Fisher's Bed 8).
Reported distribution. Spinizonocolpites echinatus s.s. is reported as rare in the Senonian of Sarawak, is present in the Palaeocene and Eocene and is known throughout the remainder of the Tertiary up to the Recent in that area (Muller 1968, p.12). The S. echinatus group is reported throughout the late Cretaceous and Palaeogene in the Caribbean, Venezuela and Nigeria (Germeraard et al. 1968).

In Europe the genus is reported from the Sparnacien supérieur to the Cuisian, occurring in France, the Paris Basin, Loire Atlantique, the Pau region and Bordelais, in Belgium and in the Cuisian and Lutetian of Spain (Gruas-Cavagnetto 1977, p.54,55).

Collinson et al. (1981) report the genus from the Ypresian and Lutetian (upper part of the London Clay Formation to the top of the Selsey Formation, Bracklesham Group) at Whitecliff Bay, Isle of Wight and in the Ramnor Inclosure Borehole, Hampshire Basin. Gruas-Cavagnetto (1976a) records a similar distribution in the Hampshire Basin. The genus has not been recorded in the London Basin.

OTHER TAXA:

Chasmatosporites apertus (Rogalska) Nilsson 1958 sensu Schulz 1967 (reworked)
Chasmatosporites major Nilsson 1968 (reworked).
Chasmatopollenites sp. see plate 2, fig.12.
Clavatipollenites sp. see plate 3, fig.4,5,7,8.
Observed distribution. Details of distribution not recorded. Illustrated specimens from Woolwich Beds (Oldhaven Gap OG12), Bracklesham Beds (Bed 1 sensu Eaton, AB57, Alum Bay).
Liliacidites spp. Undifferentiated. See plate 3, fig.6.
Monocolpopollenites tranquillus (Potonié) Thomson & Pflug 1953. See plate 3, fig.9-13 and Thomson & Pflug 1953, pl.4, fig.25,26,29,35,39,40; Gruas-Cavagnetto 1968, pl.2, fig. 10.

Monocolpopollenites sp. undifferentiated.

Ovalipollis ovalis Krutzsch 1955 emend. Klaus 1960 (reworked). See plate 3, fig.23 and Herngreen & De Boer 1974, pl.1, fig.9; Morbey & Dunay 1978, pl.4, fig.3.

SUBTURMA: DICOLPATES Erdtman 1947

Dicolpopollis luteticus (Gruas-Cavagnetto 1967b) Gruas-Cavagnetto 1976d.

See plate 3, fig.14,17, aff. D. luteticus fig.18,19 and Gr.-Cav. 1968, pl.2, fig.11-21 (as Disulcites luteticus). Comments. The specimen illustrated on plate 3, fig. 18,19 (D. aff. luteticus) shows greater variation in the size of the lumina of the reticulate ornament than is usual for D. luteticus. Both morphological types have been included in Dicolpopollis spp. in counts.

SUBTURMA: TRIPTYCHES (Naumova 1939) Potonié 1960 and PTYCHOTRIPORINES (Naumova 1937?, 1939) Potonié 1960

Comments. Tricolpate and tricolporate pollen is common at some horizons in the early Tertiary deposits of southern England, particularly the small, long-ranging species Cupuliferoidaepollenites (librarensis/microhenrici group), Tricolpites parvus, and Tricolporopollenites cingulum. Fraxinopollis variabilis and other small reticulate tricolpate pollen (Tricolpopollinites retiformis group) are less common while most other species are generally rare, with only a few specimens in each sample. Identification of the non-descript forms is difficult under these circumstances. Consequently only those species with distinctive morphology have been distinguished below, the others have been placed in broad, undifferentiated groups; Tricolpate spp. and Tricolporate spp. in the counts.

Genus: CUPULIFEROIDAEPOLLENITES Potonié, Thomson & Thiergart 1950 ex Potonié 1960.

Type species: Cupuliferoidaepollenites liblarensis Thomson, in Pot., Thoms. & Thierg. 1950, pl.B, fig.26.

Cupuliferoidaepollenites spp. (liblarensis/microhenrici group).

Plate 3, fig.20-22, cf. fig. 15,16.

1953 Tricolpopollenites liblarensis (Th.) Th.& Pf. subsp. liblarensis (Th.) Th.& Pf. p.96,97, pl.11, fig.111-132; subsp. fallax (R.Pot. 1934) Th.& Pf. pl.11, fig.133-151.

1953 Tricolpopollenites microhenrici (R.Pot.) Th.& Pf. subsp. intragranulatus Pf. p.96, pl.11, fig.81,82,84, 87,89,99,100 only.

1968 Tricolpopollenites liblarensis (Th. 1950) Th.& Pf. 1953 subfsp. liblarensis (Th. 1950) Th.& Pf. 1953; Gr.-Cav., p.62, pl.6, fig.2; subfsp. fallax (R.Pot. 1934) Th.& Pf., p.63, pl.6, fig.3,4.

1973 Tricolpopollenites liblarensis (Thomson) Th.& Pf. 1953; Tschudy, pl.4, fig.31-33.

1976 Cupuliferoidaepollenites sp. (14-19 micron size) Potter, pl.2, fig.18-19.

Comments. The pollen included here are all small (less than 20 microns long), prolate and have long colpi which almost reach to the poles. Occasionally there are very indistinct "pores" (= geniculus of Thomson & Pflug 1953, p.96). Wall structure is variable. In such small grains it is often difficult to distinguish between surface ornament and internal wall structure; the granular, baculate, fossulate and rugulate structures described by Thomson & Pflug (1953, p.96). Specimens from southern England often appear granular in outline and have an indistinct baculate or granular structure at the poles (pl.3, fig. 20,21 and compare Th.& Pf. 1953, pl.11, fig.87) but in plan view, in the centre of the specimen, the exine appears smooth plate 3, fig. 20. More rarely the exine has a rugulate or fossulate structure (plate 3, fig.16) comparable to Quercoidites cf. Q. microhenrici, pl.2, fig.11 in Frederiksen (1980).

Specimens of this type fall within (a) T.liblarensis (Th.) Th.& Pf. subsp. liblarensis (Th.) Th.& Pf. and (b) subsp. fallax (R.Pot.) Th.& Pf. and also (c) T. microhenrici (R.Pot.) Th.& Pf. subsp. intragranulatus Pf. I have

been unable to separate these three subspecies consistently. Thomson and Pflug themselves comment that specimens transitional between T. liblarensis and T. microhenrici subsp. intragranulatus do occur, particularly in the early Tertiary (1953 p.96). I have therefore placed all variations in a broad liblarensis/microhenrici group.

C. cf. liblarensis (see below) probably falls within T. liblarensis subsp. fallax as described by Thomson & Pflug but is readily distinguishable from the liblarensis/microhenrici group by its consistently smaller size (less than 14 microns length), its completely smooth exine and by its tendency to oblique compression.

OTHER SPECIES:

Cupuliferoidaepollenites cf. liblarensis Th. 1950 ex Potonié 1960. See plate 4, fig. 1,2.
Comments: These small, subprolate, tricolpate pollen are similar to the liblarensis/microhenrici group (see above) but are smaller; less than 14 microns in length, are generally completely smooth without any exine structure or ornament and (as a result of their subprolate shape) are more frequently preserved in oblique orientations.

Genus: MARGOCOLPORITES Ramanujam 1966 ex Srivastava 1969a
Type species: Margocolporites tsukadae Ramanujam 1966 (subsequently designated by Srivastava 1969a).

Margocolporites cf. lihokus Srivastava 1972.
Plate 4, fig. 3-6.

cf.1972 Margocolporites lihokus Srivastava, p.264, pl.20, fig.3-5.

Comments. London Basin specimens are prolate to subprolate, rather than oblate spheroidal, and are smaller than Srivastava's specimens (equatorial diameter 23 microns rather than 34-45 microns). They are entirely similar in the presence of clear costae (margo of Srivastava), large lalongate pores and in the reticulate ornament, with lumina larger on the mesocolpia becoming smaller towards the poles

and colpi. Srivastava includes Eksik's specimens of Tricolporopollenites kruschi (1968, pl.32, fig.4-5, and pl.33, fig.1-3, 8) within M. lihokus but in these grains the muri of the reticulum are coarser than in the London Basin material.

Size. Length 33 microns. Equatorial diameter 23 microns; 2 specimens.

Botanical affinity. Unknown.

Observed distribution. Rare, recorded only from the Reading beds of Pincents Kiln and the London Clay at Leaden Roding.

Reported distribution. Palaeocene of Alabama, Srivastava (1972).

Genus: NYSSAPOLLENITES Thiergart 1937.

Type species. Nyssapollenites (al. Pollenites) pseudocruciatus (R.Pot. 1931a, p.328, pl.1, fig.10) Thiergart 1937.

Nyssapollenites sp. A. sp. nov.

Plate 4, fig. 8-11.

Description. (Based on 10 specimens). Pollen grains oblate to spheroidal, tricolporate, commonly preserved in oblique orientation. In polar view outline triangular with convex sides. Colpi indistinct, long, reaching three quarters of the way to the pole; bordered by narrow costae up to 1 micron wide but sometimes poorly defined (plate 4, fig.8). Pores rounded to oval, c.5 microns in diameter, very slightly lalongate, surrounded by distinct but irregular endannuli 1.5 microns thick.

The exine is two layered, tegillate, 1.0-1.5 microns thick in the mesocolpia. The endexine is homogenous, equal in thickness to the ektexine. In some specimens two layers are visible within the endexine (plate 4, fig.9), the endexine and foot layer of Larson et al. (1962). The ektexine is pilate; the heads (capita) of the pila are well defined and are in contact forming a tegillum. The capita project to give the grains a granular outline. In plan view grains are also distinctly granular in appearance, grana may be isolated or aligned in short, straight or arcuate rows(plate 4, fig. 8).

Ornament, as distinct from structure, is difficult to determine with the light microscope (see plate 4, fig. 9) but SEM examination shows an irregular rugulate to striate ornament (plate 4, fig. 10).

Adjacent to the endannuli the exine thins to less than 1 micron. This thinning occurs in all exine layers, including the bacula of the pila, so that the thinned zone appears to consist of only the endexine (sensu Larson et al. 1962) with irregular remnants of the foot layer of the ektexine (plate 4, fig. 8,9,11) and an outer tegillum. Details of the ornament over these thinned areas are difficult to resolve with the light microscope but SEM studies show the rugulate to striate ornament continuing across them to the edge of the colpi (plate 4, fig. 10,11).

Size. Polar view, 4 specimens; 25.0 (28.75) 30.5 microns; equatorial view, 1 specimen; polar axis 21.0 microns, equatorial axis 22.5 microns.

Typical specimen. PK4/5, single spore mount. Plate 4, fig.8; diameter 29.5 microns. Locality; Woolwich and Reading Beds, sample PK 4, Pincents Kiln, near Reading. GR: SU 653722.

Comparison. Differs from Nyssapollenites sp. B in the nature of the pores which are lalongate and more gaping, in the less hexagonal amb and the granular outline produced by the well developed capita of the pila. Tricolporopollenites kruschi is a broad species and specimens comparable to Nyssapollenites sp. A. and sp. B may have been included in it. However, the indistinct nature of the colpi, and pronounced exine thinning adjacent to the endannuli distinguish Nyssapollenites sp. A and sp. B.

Botanical affinity. Probably Nyssaceae.

Observed distribution. This is a characteristic but rare element in the Woolwich and Reading Beds at the western end of the London Basin. It occurs as clusters in PK 4 and is probably a representative of the local flora there. It is very rare in the Thanet Beds, South Lambeth Borehole and the London Clay from the Leaden Roding Borehole.

Nyssapollenites sp. B. sp. nov.

Plate 4, fig.7.

Description. (Based on 8 specimens). Pollen grains tricol-

porate, oblate to spheroidal. Most commonly preserved in polar compression, outline rounded triangular to hexagonal, with straight to weakly convex sides. Colpi indistinct; slit like, rarely gaping at the equator; long, almost reaching the poles. Colpi bordered by poorly defined costae, c.1 micron wide, which continue into the endannuli at the pores. Pores circular to oval, "tight", rarely gaping, weakly lolongate, c.3 microns in diameter but difficult to measure because of the well developed endannuli up to 2 microns thick.

The exine is tegillate, 2.0-2.5 microns thick in the mesocolpia comprising endexine (in which foot layer and endexine sensu Larson et al. 1962 are visible, both c.0.5 microns thick) and pilate ektexine. Bacula and capita are c.0.5 microns high. Individual capita are poorly defined and not always discernible, they are fused to form a tegillum but do not project above it. Grains are therefore generally smooth to weakly undulating in outline. It is difficult to distinguish ornament from structure; grains have a granular to microreticulate appearance in plan view.

Adjacent to the endannuli the exine thins to c.0.5 microns, this thinning is visible as areas of lighter exine radiating from the endannuli. The bacula appear to be absent from this area.

Size. 7 specimens; polar view 21.75 (24.0) 26.0 microns

Typical specimen. PK6/31, single spore mount, plate 4, fig. 7; diameter 25 microns. Locality; Woolwich and Reading Beds (sample PK 6) at Pincents Kiln, Berkshire G.R: SU 653722.

Comparison. See discussion for Nyssapollenites sp. A. above.

Botanical affinity. Probably Nyssaceae.

Observed distribution. Recorded only from the Woowich and Reading Beds at Pincents Kiln, where it is rare.

OTHER SPECIES:

Nyssapollenites sp.

See plate 4, fig.12,13,16.

Genus: RHOIPITES Wodehouse 1933

Type species: Rhoipites bradleyi Wodehouse 1933, p.513, Fig.45.

Rhoipites sp. A. sp. nov.

Plate 4, fig.14,15, 17-22.

Description. Pollen grains tricolporate, rarely tetracolporate; spheroidal to subpro late in shape, rounded triangular in polar view, frequently preserved in oblique orientation. Colpi long, bordered by obvious costae, continuous around the polar end of the colpi and 1.0-1.5 microns deep in optical section (plate 4, fig.17,21). Pores large, shape poorly defined, ?circular to oval, lalongate, length (polar extension) 3.5-6 microns, width 4.0-8 microns. Exine 1.5-2.0 microns thick, with inner homogenous layer (endexine) about twice as thick as ektexine. In some specimens with differential staining two distinct layers are visible within the endexine and probably represent the endexine proper and the foot layer of the ektexine (terminology of Larson, Skvaria & Lewis (1962) illustrated in Kremp, 1969, fig.545). Ektexine with reticulate ornament; muri supported by pila 0.5-1.0 micron high, heads clearly visible, giving a beaded appearance to the outline of the grain. Lumina of reticulum irregular in shape and variable in size, 0.5-1.5 microns. Muri less than 1 micron wide.

Size. Diameter (polar view) 22.5 (23.0) 23.5 microns, 3 specimens; equatorial view, length 18.0 (22.0) 23.5 microns, width 17.5 (18.5) 21.0 microns, 6 specimens.

Typical specimen. Plate 4, fig.15,17,18. Samples PK6b; EF: W43 Second example; PK6/34 single spore mount; plate 4, fig. 19.

Locality. Pincents Kiln, near Theale, Berkshire.

Comparison. Rhoipites globosus Stanley 1965 is similar in size and ornament but lacks the thick endexine present in Rhoipites sp. A. Tricolporopollenites fsp. A. Ollivier-Pierre 1974, (p.45, pl.24, fig.13-14c) is very similar, it differs only in its smaller, better defined pores and narrower costae. Similarly Tricolporopollenites crassiexinus Krutzsch & Vanhoorne 1977 (p.75, pl.42, fig.24-28) has much smaller pores (c.2 microns) and narrower costae.

Botanical affinity. Unknown.

Observed distribution. Present in the Woolwich and Reading Beds at Pincents Kiln. Rare elsewhere (see Appendix 2).

Rhoipites sp. B. sp. nov.

Plate 4, fig.23-26, Plate 5, fig.1-3.

Description. (Based on 15 specimens). Pollen grains sub-prolate, rarely prolate, frequently preserved in oblique orientation. Tricolporate, colpi long, almost reaching the poles; usually narrow, parallel sided, rarely gaping. Colpi bordered by costae, thickest (2.0 - 2.5 microns) near the equator adjacent to the pores and tapering towards the poles where they merge with endexine of normal thickness. Costae most obvious when seen in lateral compression (plate 5, fig.1,2) often appearing indistinct in plan view(plate 4, fig.23) or in grains in oblique orientation (plate 4, fig.25). Pores large, 3.5 - 6.5 microns, circular to oval, usually interrupted by wedge-shaped slits 2.5 - 5.0 microns long, extending parallel to the equator (pl.4, fig.26, pl. 5, fig.2). Exine 1.5 - 2.0 microns thick in the mesocolpia, two-layered, endexine and ektexine of equal thickness. Endexine homogenous, two layers discernible in some specimens. Ektexine pilate, supporting rods (bacula) and heads of pila (capita) of equal thickness; tegillum formed by fusion of the capita. Ornament scrobiculate to reticulate (pl.4, fig.24, pl. 5, fig.3), formed by pits within the outer surface of the tegillum. Scrobiculi rounded to oval in shape, usually less than 0.5 microns in diameter, intervening muri 0.5 - 1.0 micron wide, often showing a granular structure (columellae seen in plan view) which may obscure the scrobiulate ornament (plate 4, fig.26).

Size. Equatorial view, 5 specimens; length 25.0 (27.5) 32.0 microns; width 17.0 (21.0) 23.5 microns.

Typical specimen. NB1(4);300963, plate 5, fig.1-3; length 26.0 microns, width 17.0 microns. Locality, sample NB 1, Reading facies of Woolwich and Reading Beds, Cold Ash Quarry, near Newbury, Berkshire. GR:SU 501713.

Comparison. The scrobiculate ornament and distinctive pore

structure distinguish this from other tricolporate pollen. Retitricolporites macrodurensis (Th.& Pf. 1953) Roche & Schuler 1976 (pl.11, fig.20-22) from the Oligocene of Belgium has similar wall structure and ornament but is more prolate in shape and lacks the slit-like equatorial extensions of the pores which characterise Rhoipites sp. B. Rhoipites cryptoporus Srivastava 1972 is more distinctly reticulate and pilate, with conspicuous capita, in contrast to the almost smooth outline of Rhoipites sp. B. Pore structure is also different.

Botanical affinity. Possibly Araliaceae, see specimens illustrated by Gruas-Cavagnetto and Bui 1976.

Observed distribution. Fairly common in sample NB 1 from Cold Ash Quarry, near Newbury, rare elsewhere.

OTHER SPECIES:

Rhoipites psinnus Stanley 1965.

See plate 5, fig.4 and pl.42, fig.17-22 Stanley 1965.

Size. 6 specimens, equatorial diameter; 13.0 (13.25) 14.0 microns; 3 specimens, polar axis 11.5, 13.5, 15.0 microns.

Observed distribution. Fairly common in the Reading facies of the Woolwich and Reading Beds at Pincents Kiln, very rare elsewhere.

Reported distribution. Infrequent to common in the late Cretaceous and Palaeocene of South Dakota (Stanley 1965).

Genus: TRICOLPITES Cookson ex Couper 1953.

Type species: Tricolpites reticulatus Cookson 1947; subsequent designation Couper 1953.

Tricolpites parvus Stanley 1965

Plate 5, fig.5-14, cf. fig.15-17.

1965 Tricolpites parvus Stanley; p.322, pl.47, fig.28-31.

1971 Tricolpites parvus Stanley 1965; Leffingwell p.44, pl.8, fig.4a,b.

?1977 Tricolporopollenites eocaenicus W. Kr.& Vanh. p.75, pl.32, fig.4-9.

Comments. Although all specimens included here are comparable in general morphology there is considerable variation in the details of the colpus. The pollen grains are oblate to spheroidal; exine is 1.5-2 microns thick with a homogenous endexine, usually twice as thick as the ektexine; ektexine is reticulate, lumina are usually less than 1 micron wide. In some specimens there is no sign of a colpal membrane (plate 5, fig.5, compare Stanley 1965, pl.47, fig.30, 31), some have a complete, granular colpal membrane (plate 5, fig.6,7) while others have a torn, folded colpal membrane which appears similar to costae (plate 5, fig.10,11).

This species is distinguished from other small reticulate pollen grains by the relative thickness of the endexine. I do not agree with Elsik who includes T. parvus in Tricolpopollenites hians (Stanley) Elsik 1968.

Observed distribution. Present in all formations examined.

Reported distribution. Early Palaeocene, South Dakota (Stanley 1965); Lance and Fort Union Formations (Maastrichtian and early Palaeocene respectively) of Wyoming (Leffingwell 1971).

Tricolpites sp. A. sp. nov.

Plate 5, fig.18-21.

Description. (Based on 10 specimens). Pollen grains prolate, tricolpate, occasionally with geniculi; colpi long, almost reaching the poles; apocolpia small, 2-3 microns in diameter. Exine 0.75-1.0 micron thick in the mesocolpia tapering to less than 0.5 microns adjacent to the colpi. Endexine very thin, less than 0.5 microns; ektexine 0.5-c.1.0 micron, pilate, with reticulate ornament on the mes- and apocolpia; muri less than 0.5 microns wide; lumina rounded or elongated in shape, never angular, ranging from less than 0.5 to 1.5 microns, most commonly less than 1 micron. Colpi bordered by smooth to scabrate areas, up to 2 microns wide (margines sensu Faegri & Iversen 1950).

Size. 10 specimens; length 14.5 (16.0) 19.5 microns; width 10.5 (11.5) 13.5 microns.

Typical specimen. JL 867b;250962, plate, 5, fig.20,21. length 16.5 microns; width 13.0 microns. Locality, sample JL 867, Woolwich Shell Beds from a temporary exposure in a road cutting at Shorne Wood, Kent, GR: TQ 673698.

Comparison. Tricolpites sp. A is distinguished from other small reticulate, tricolpate pollen by the broad, smooth to scabrate margines. Tricolporopollenites diversireticulatus Roche 1973 (pl.5, fig.55) and T. esteouleae Ollivier-Pierre 1974 (pl.6, fig.9-10, pl.7, fig.2) are similar in size and in their reticulate ornament but both have weak pores and clear costae.

Botanical affinity. Unknown.

Observed distribution. Common in the lignite at the base of the Woolwich Shell Beds at Shorne Wood, Kent; rare in the Woolwich Shell Beds. Very rare elsewhere.

Tricolpites sp. B. sp. nov.

Plate 5, fig.22-24.

Description. (Based on 10 specimens). Pollen grains subprolate, tricolpate, occasionally with geniculi. Colpi long, almost reaching the poles, margins ragged. Exine 1.5 - 2.0 microns thick, two layered, ektexine twice as thick as endexine. Endexine homogenous, c.0.5 microns thick. Ektexine pilate, supporting rods (bacula) and heads of pila (capita) of equal height; tegillate, tegillum formed by fusion of the capita. Ornament scrobiculate (plate 5, fig.22), pits circular to oval, less than 1 micron wide, usually c.0.5 microns. Bacula closely spaced, in plan view giving a granular to microreticulate appearance (structure) which can mask the scrobiculate ornament (plate 5, fig.24).

Size. Equatorial view, 5 specimens; length 24.5 (27.75) 32.0 microns; width 22.0 (24.0) 28.0 microns.

Typical specimen. JL 865c;328982, plate 5, fig.22,23; length 32.0 microns, width 28.0 microns. Locality; JL 865; lignite horizon within the Woolwich and Reading Beds, at Shorne Wood, Kent, G.R. TQ:67306980.

Comparison. The scrobiculate - reticulate exine distinguishes this from other tricolpate pollen. Rhoipites sp. B

(herein) has similar exine structure but is clearly tricolporate. Specimens of Favitricolporites baculoferus (Pf.) Srivastava with poorly developed costae are superficially similar but the capita are better developed and the pila more widely spaced making the pilate nature of the exine more obvious. However transitional forms do occur.

Botanical affinity. Unknown.

Observed distribution. Generally rare in the Woolwich and Reading Beds, lignite and Shell Beds, at Shorne Wood. Fairly common in the Reading facies of the Woolwich and Reading Beds at Cold Ash Quarry, nr. Newbury and at Knowl Hill.

Tricolpites sp. C. sp. nov.

Plate 5, fig.26-28.

Description. (Based on 10 specimens). Pollen grains oblate to spheroidal, generally compressed in polar view; tricolpate; reticulate. Colpi long, extending two-thirds of the way from the equator to the poles, each bordered by a narrow ridge less than 0.5 microns wide (margo of Chmura 1973). Colpal membranes usually preserved, composed of two zones, a smooth area adjacent to the "margo", 1.5 - 2.0 microns wide, and a central, granular area 1.0 - 1.5 microns wide (plate 5, fig.26,27). Exine 0.5 - 1.5 microns thick, two layered; endexine thin, less than 0.5 microns; ektexine baculate, bacula 0.5 - 1.0 micron high. Ornament reticulate, lumina irregular in shape and size, varying from less than 0.5 microns to 2 microns in length but fairly even in size on individual grains (compare plate 5, fig.28 , less than 0.5 - 1.0 microns and plate 5, fig.26,27, generally 1.5 microns). Muri narrow, less than 0.5 microns, simplibaculate with bacula at junctions of muri.

Size. Polar view, 9 specimens, 24.0 (25.75) 31.0 microns.

Typical specimen. PK21D(2) EF:L47/2, plate 5, fig.26,27; diameter 23.0 microns. Locality; sample PK 21, Reading facies of the Woolwich and Reading Beds, Pincents Kiln, Berkshire, GR:SU 653722.

Comparison. Tricolpites concinnatus Chmura 1973 (p.109, pl.22, fig.15-18), from the Late Cretaceous (Campanian-Maastrichtian) of California, is very similar. It differs in the more regular, angular shape of the lumina and poorer development of colpal membranes. The size of the reticulation in the present material also appears more variable, with a gradation from specimens with lumina 0.5 - 1.0 microns to those with lumina 1.5 - 2.0 microns.

Tricolpites sp. C. differs from Retitrescolpites anguloluminosus Anderson in the smaller, more irregularly shaped reticulum and the presence of colpal membranes, although Chmura (1973, p.109) notes remnants of colpal membranes in some of her specimens of R. anguloluminosus.
Botanical affinity. Possibly Hamamelidaceae. Chmura considers T. concinnatus to be generally similar to the pollen of Bucklandia (Hamamelidaceae).
Observed distribution. Rare in the Reading facies of the Woolwich and Reading Beds, Pincents Kiln.

Genus: TRICOLPOROPOLLENITES Pflug & Thomson 1953.
Type species: Pollenites dolium R. Potonié 1931a, p.329, pl.2, fig.22.

Tricolporopollenites cingulum (Potonié 1931) Pf. & Th. 1953.

Plate 5, fig.26,29.

1931b Pollenites cingulum R. Potonié; p.26, pl.1, V45a, 46a,b, 48b, 60a,d, 61c, 62c only.
1951b Cupuliferoipollenites pusillus Pot. pl.20, fig.69.
1951b Pollenites fusus R. Pot. 1931; Potonié, pl.20, fig.80-83.
1951b Pollenites cingulum R. Pot. 1934; Potonié pl.20, fig.84-87.
1953 Tricolporopollenites cingulum (R. Pot.) Pf.& Th.; subsp. fusus (R. Pot.) Pf.& Th.; p.100, pl.12, fig.15-27; subsp. pusillus (R.Pot.), Pf.& Th.; p.100, pl.12, fig.28-41; subsp. oviformis (R.Pot.) Pf.& Th.; p.100, pl.12, fig.42-49.

1968 Tricolporopollenites cingulum (R.Pot. 1931) Th.& Pf. 1953 subfsp. oviformis (R.Pot. 1931) Th.& Pf. 1953; Gr.-Cav. pl.7, fig.1,3; subfsp. pusillus (R. Pot. 1934) Th.& Pf. 1953; Gr.-Cav. pl.7, fig.2.

1976a Tricolporopollenites cingulum (R.Pot. 1931) Th.& Pf. 1953 oviformis Th.& Pf. 1953; Gr.-Cav. pl.3, fig. 22,23.

1980 Castanea sp. Christopher et al. pl.3, fig.15,16.

1980 Cupuliferoipollenites spp. Frederiksen, pl.2, fig. 21-23.

Comments. There is considerable variation in this species. Thomson & Pflug (1953) recognised several subspecies and Potonié himself raised several of these to species level (1951a,b). However, the distinction between them is not always clear, I have therefore used the species cingulum in its broadest sense.

Botanical affinity. Castanea (Potonié 1960, p.98), Castanea, Castanopsis (Gr.-Cav. 1976, plate explanation, pl.3, fig.22,23).

Observed distribution. Present in all formations examined except the Oldhaven Beds.

Reported distribution. Widespread in central Europe, from Palaeocene to Miocene (Thomson & Pflug 1953). Present in the U.S.A. from at least the base of the Tertiary in the Gulf Coast (Fairchild & Elsik 1969) and from the Palaeocene to Oligocene in South Carolina (Frederiksen 1980).

Tricolporopollenites mansfeldensis Krutzsch 1969a. Plate 5, fig.30-33, Plate 6, fig.1-3.

1976a Tricolporopollenites mansfeldensis W.Kr. 1969a; Gr.-Cav. pl.2, fig.25,26.

cf.1974 Tricolporopollenites milonii O.-Pierre, p.84, pl.5, fig.7-11.

1977 Tricolporopollenites mansfeldensis W.Kr. 1968; W.Kr. & Vanh., p.69, pl.43, fig.29-32.

1978 cf. Tricolporopollenites milonii O. Pierre 1976 (=1974 herein); Collinson pl.9.2, fig.14.

non 1977 Tricoloporopollenites fsp. (ex.gr. mansfeldensis W.Kr.); W.Kr.& Vanh. p.69, pl.29, fig.14-21.

Description. Pollen grains spheroidal, 3-4 colporate; colpi short, parallel-sided, about half the length of the grain; endoapertures greatly elongated equatorially (rugae of Thomson & Pflug 1953 p.20), barely shorter than the colpi; colpi bordered by very wide costae (thickened endexinous pads), oval in outline and interrupted at the equator by the parallel-sided rugae (plate 6, fig.1). Exine at poles and between apertures 1.0 - 1.5 microns thick, two layered. Ektexine scabrate to weakly fossulate, endexine smooth, occasionally with irregular channels and grooves particularly at the edge of the costae (see plate 5, fig.31-33, this may be a preservational feature).

Size. Polar view 6 specimens; 26.0 (29.5) 31.0 microns; length (equatorial view) 1 specimen; 26.0 microns.

Comments. The distinction between T. mansfeldensis and T. milonii is not clear; it is possible that the latter is a junior synonym. Quadrapollenites vagus (Stover) Elsik has similar endexinal thickenings but is more prolate in shape and lacks well developed rugae.

Botanical affinity. Unknown.

Observed distribution. Common at some horizons in the Woolwich and Reading Beds from Cold Ash Quarry, Newbury (cf. Collinson, 1978, who reports cf. T. milonii as forming 30% of her Assemblage 1 from Cold Ash Quarry). Rare elsewhere.

Reported distribution. London Clay, Lower Bagshot Beds and Fisher Bed VII (Gruas-Cavagnetto 1976a); regionally present in the early Tertiary of central Europe (W.Kr.& Vanh. 1977).

Tricolporopollenites megareticulus Krutzsch & Vanhoorne 1977

Plate 6, fig.4-7.

1977 Tricolporopollenites megareticulus W.Kr. & Vanh. p.81, pl.34, fig.36-42.

Comments. This species is characterised by the very large reticulum (lumina 4-5 microns wide) and, in specimens from the London Basin, by the separation of the reticulate layer (?ektexine) from a distinct, homogenous inner layer

(?endexine), see plate 6, fig.4,7. Krutzsch and Vanhoorne comment on the obscure nature of the apertures in the endexine; however well developed endo-colpi are visible in some of my specimens although they do not gape to the same extent as the colpus in the "ektexine" (plate 6, fig. 6,7). No endopores have been seen.

The distinction between this species and Retitrescolpites anguloluminosus (And.) Frederiksen is not clear. I have included in T. megareticulus only specimens with large lumina which also show a distinct homogenous endexine and a separation of the exine layers. It is possible however that this is a preservational feature and that T. megareticulus is a junior synonym of R. anguloluminosus.

Size. 7 specimens, equatorial diameter; 22.0 (26.0) 33.0 microns, small compared with Krutzsch & Vanhoorne's Belgian material (30-40 microns).

Botanical affinity. Unknown.

Observed distribution. Very rare, only seen in the Woolwich and Reading Beds.

Recorded distribution. Middle Palaeocene-early Eocene in Central Europe (W.Kr. & Vanh. 1977).

OTHER SPECIES:

Tricolporopollenites aceroides Krutzsch 1961d
See plate 6, fig.13,14 and Krutzsch 1961d, pl.5, fig.125-128 ; W.Kr. & Vanh. 1977, pl.32, fig.39-41.

Tricolporopollenites baculatus Krutzsch 1961d

Tricolporopollenites duplibaculatus Gruas-Cavagnetto 1966.
See plate 6, fig.8-12
and Gr.-Cav. 1966, pl.2, fig.13-15.
Size. 5 specimens, length 23.5 (25.0) 27.0 microns.

Tricolporopollenites iliacus (R.Pot. 1931d) Pf. & Th. 1953
See plate 6, fig.16 and forma medius Pf. & Th. 1953 in Gr.-Cav. 1968, pl.7, fig.18-20, and 1976a, pl.7, fig.16.

Tricolporopollenites kruschi (R.Pot. 1931c). Th. & Pf. 1953
See plate 6, fig.22,23 and Chateauneuf & Gruas-Cavagnetto 1968, pl.3, fig.8.

Tricolporopollenites margaritatus (R.Pot. 1931a)
Th. & Pf. 1953.

See plate 6, fig.15 and Th. & Pf. 1953, pl.14, fig.74.

Tricolporopollenites megaexactus (R. Pot. 1931b) Th. & Pf. subsp. exactus (R. Pot.) Th. & Pf. 1953.

See plate 6, fig.20,21.

Tricolporopollenites microiliacus Pflug & Thomson 1953.

Tricolporopollenites salardae Gruas-Cavagnetto 1976a.

Tricolporopollenites cf. sittlerii Roche 1973.

See plate 6, fig.24 and Gr.-Cav. 1976a pl.2, fig.21 only; not Roche 1973, pl.6, fig.18-19.

Tricolporopollenites sp. A

See plate 7, fig.1,2,5 and Gr.-Cav. 1977 (thesis) pl.12, fig.1-4, p.138 (as "Tricolporopollenites srivastavai").

Comments. The verrucate ornament is slightly finer on my specimens, grains are otherwise comparable to "T. srivastavai".

Observed distribution. Alum Bay only, AB 60, AB 63, Bracklesham Beds, Bed 1 sensu Eaton 1976.

Reported distribution. Cuisian, Paris Basin (Gr.-Cav. 1977).

OTHER TAXA:

Aesculiidites circumstriatus (Fairchild 1966) Elsik 1968.

See plate 6, fig.17-19 and Fairchild 1966, pl.2, fig.3a-3c (as Tricolpites circumstriatus); Elsik 1968, pl.27, fig.10-18; Chat. & Gr.-Cav. 1968, pl.4, fig.21-22 (as Tricolpites fsp. P.160).

Size. 10 specimens, equatorial diameter, polar view; 15.0 (17.0) 19.0 microns.

Comments. The arrangement of the ornament, concentric about the poles, distinguishes this from other tricolporate species with striate-reticulate ornament.

?Brevicolporites sp.

See plate 7, fig.18,19.

Comments. Too few specimens for positive identification, superficially similar to Brevicolporites colpella Anderson 1960, pl.6, fig.11-14. Included in "brevicolpate/colporate pollen" in counts.

Cornaceoipollenites parmularius (R.Pot.) Potonié 1960.

See plate 7, fig.6,8-10 and

Tricolpopollenites magnus Kedves 1965b in Gr.-Cav. 1976a, pl.1, fig.15,24; Tricolporopollenites parmularius (R.Pot.) W.Kr. 1960 cf. parmularius in W.Kr. & Vanh. 1977, pl.29, fig.1-8.

Size. 10 specimens; length 37.5 (40.25) 45.0 microns.

Observed distribution. Relatively common in the lignite horizons of the Woolwich and Reading Beds, otherwise very rare.

Cupanieidites eucalyptoides Krutzsch 1962a

See plate 7, fig.13 and Krutzsch 1970, pl.6, fig.130; W.Kr.& Vanh. 1977, pl.17, fig.13-15.

?Cyrillaceaepollenites sp. (unidentified)

See plate 7, fig.14-16.

Comments. Too few specimens were recovered for definite identification. The pollen grains are oblate, preserved in polar view and are characterised by very short colpi, between 1/3 and 2/3 of the radius. Exine is thin, up to 1 micron, and is smooth to scabrate. No definite pores have been seen but the thinning of the exine adjacent to the colpi at the equator suggests the presence of pores with pronounced equatorial elongation. Similar specimens are recorded by Tschudy 1973, pl.4, fig.20,21 as Cyrillaceaepollenites of the Pollenites ventosus type (B.17) and Frederiksen 1980, pl.3, fig.24,?25 as Pseudolaesopollis ventosa (Pot.) Frederiksen.

Duplopollis golzowense Krutzsch 1961d

See plate 7, fig.12 and Krutzsch 1961d, pl.2, fig.43-45.

Comments. Only a single specimen recorded, from the Thanet Beds at Oldhaven Gap.

Duplopollis myrtoides Krutzsch 1959

?Faguspollenites sp.

See plate 7, fig.7.

Comments. Similar to Faguspollenites Raatz 1937 (as in Potonié 1960, pl.6, fig.116) in the spheroidal shape and very short colpi but no definite pores seen. Too few specimens for positive identification. Included in "brevicolporate pollen" in counts.

Favitricolporites baculoferus (Pflug 1953a) Srivastava 1972

See plate 7, fig.11 and Thomson & Pflug 1953, pl.14, fig.4,5; Elsik 1968, pl.26, fig.1,2 only (both as Tricolporopollenites baculoferus); Gr.-Cav. 1968, pl.6, fig.26 only (as Tricolpopollenites vermiculatus); Srivastava 1972, pl.16, fig.1-9 and Christopher et al. 1980. pl.1, fig.5-7.

cf. Favitricolporites baculoferus (Pflug 1953a) Srivastava 1972

See plate 7, fig.17.

Comments. Specimens of this type appear to be transitional between F. baculoferus and Tricolpites sp. B. Wall structure is generally similar to the scrobiculate to reticulate exine of Tricolpites sp. B although the reticulation is more obvious than in that species. The capita of the pila are not as well developed as in F. baculoferus but the tricolporate apertures with weakly developed costae are closer to the latter species than to Tricolpites sp. B.

Observed distribution. Fairly common in the Reading facies of the Woolwich and Reading Beds at Cold Ash Quarry, near Newbury.

Fraxinoipollenites variabilis Stanley 1965

See plate 7, fig.3,4, plate 8, fig.1-3, cf. fig.4,5 and Stanley 1965, pl.45, fig.29-30, 32-33 only; Gr.-Cav. 1976a, pl.1, fig.28; Schumacker-Lambry 1978, pl.14, fig.1-4, (as Tricolpopollenites hians); NOT Fraxinoipollenites variabilis Stanley in Leffingwell 1971, pl.8, fig.8-10; NOT Potter 1976, pl.2, fig.37, as Aesculiidites variabilis (Stanley 1965) Nichols 1970 (colpate form).

Comments. From the literature this species appears to be the most appropriate for my material. However, specimens illustrated as F. variabilis by several authors are not comparable (see above and Tricolpites cf. T. variabilis Stanley 1965 in Christopher et al. 1980). Of the London Basin material plate 7, fig.3, plate 8, fig.1,2 are the most characteristic (comparable with Stanley 1965, pl.45, fig.33,34) while the shorter ornament on plate 8, fig.3

is closer to that on the holotype (Stanley 1965, pl.45, fig.29-30).

Pentapollenites spp. (undifferentiated).

See plate 8, fig.6-10 and

P. pentangulus (Pflug 1953a) Krutzsch 1958, pl.10, fig. 5-7; Gr.-Cav. 1976, pl.6, fig.8; W. Kr. & Vanhoorne 1977, pl.16, fig.1-9; and P. laevigatus W. Kr. 1962 in Gr.-Cav. 1968, pl.9, fig.18.

Retitrescolpites angululuminosus (Anderson 1960) Frederiksen 1979

See plate 8, fig.11-13,17 and Anderson 1960, pl.6, fig.15-17, pl.8, fig.17,18 (as Tricolpites angululuminosus); Simpson 1961, pl.18, fig.10,12 (as Bucklandia prebasaltica); Stanley 1965, p.320-321, pl.47, fig.18-23 (as Tricolpites bathyreticulatus); Elsik 1968, p.624, pl.24, fig.15-16, pl.25, fig.1; Christopher 1978, pl.2, fig.15 (as "Retitricolpites" sp. A), pl.2, fig.18 ("Retitricolpites" sp. D) and pl.2, fig.19 ("Retitricolpites" sp. E); Frederiksen 1979, p.139, pl.1, fig.13 and 1980, pl.2, fig.18,19 (as Retitrescolpites angululuminosus (Anderson) Frederiksen).

Spinaepollis spinosus (R. Pot. 1931) Krutzsch 1961d

See plate 8, fig.15,16 and as "Gruppe 79 spinosoide Formen" W. Kr. 1958, pl.10, fig.32-39; as Sernapollenites duratus Stover 1966, pl.1, fig.7a-d; Spinaepollis spinosa Frederiksen 1980, pl.2, fig.17.

Size. 6 specimens; equatorial diameter 25.0 (27.0) 29.5 microns.

Botanical affinity. Unknown. Although several authors have commented on the presence of similar ornament in various extant families; Lauraceae (Pflug 1953a), Euphorbiaceae (W. Kr. 1961), Thymelaceae (Elsik 1968). None of these types have similar apertures to Spinaepollis spinosus.

?Spinulaepollis spp.

See plate 8, fig.14,18,19 and Spinulaepollis sp. in Gruas-Cavagnetto 1974, pl.5, fig.32.

Observed distribution. Rare, forms comparable to plate 8, fig.19 are present in the Reading facies of the Woolwich and Reading Beds at the western end of the London Basin.

Striate tricolpate/tricolporate pollen, undifferentiated. See plate 6, fig.25. There is considerable morphological variation in this group, individual species have not been distinguished.

Tricolpopollenites retiformis Th. & Pf. 1953

See Tricolpopollenites gr. retiformis Gr.-Cav. 1968, pl.6, fig.6-7, 12-15.

SUBTURMA: POLYPTYCHES (Naumova 1937, 1939) Potonié 1960

Genus: POLYCOLPITES Couper 1953

Type species: Polycolpites clavatus Couper 1953, p.63, pl. 8, fig.123,124.

Polycolpites sp. A. sp. nov.

Plate 8, fig.20-26.

Description. (Based on 5 specimens). Pollen grains spheroidal, polycolpate, with five or six, colpi; the precise number is difficult to determine in the uncompressed grains in equatorial view. Colpi short, in polar view they extend about one third of the way to the pole. In equatorial view colpi range from 5.75-12.5 microns in length, usually 5-7 microns. In some specimens structures similar to narrow, poorly defined costae are visible at one aperture in optical section, interrupted by an apparent lolongate endopore. Exine comparatively thick for the size of the pollen, 1-1.5 microns. Endexine very thin, less than 0.5 microns, ektexine c. 1 micron, pilate with closely spaced delicate pila the heads of which unite to form a tegillum (plate 8, fig.21,25). In plan view exine is granular (plate 8, fig.26) to microreticulate, with limina c.0.5 microns (plate 8, fig.20,24).

Size. Polar view, 1 specimen (5 colpi); diameter 22.25 microns. Equatorial view, 3 specimens; polar axis 17.5 (18.0) 18.5 microns; equatorial axis 18.5 (19.0) 19.5 microns.

Typical specimen. PK 21D(3) EF:V32/1, plate 8, fig.23,24. Equatorial axis 19.0 microns; polar axis 18.5 microns. Locality; Sample PK 21; Woolwich and Reading Beds at Pincents Kiln near Reading GR:SU 653722.

Comments. The number of colpi is not always easy to determine because of the thick exine and the tendancy of grains

to be preserved in equatorial view. For the same reasons it is difficult to examine the structure of the colpi and to decide whether true pores or costae are present.

Comparison. This species is distinguished by the combined characters of small size, spherical shape and the close spacing of the delicate pila.

Botanical affinity. Unkown.

Observed distribution. Very rare, only 5 specimens recorded to date, two in sample PK 21 from the Woolwich and Reading Beds at Pincents Kiln and three from the Woolwich Marine Beds at Oldhaven Gap, sample OG 12.

SUBTURMA: PTYCHOPOLYPORINES (Naumova 1937, 1939), Potonié 1960

Tetracolporopollenites manifestus (R.Pot.) Th. & Pf. 1953 subsp. ellipsoidus Pf.

See plate 8, fig.28 and Thomson & Pflug 1953, pl.15, fig.35,36; Gruas-Cavagnetto 1976c, pl.5, fig.10-13.

Comments. Included in Tetracolporopollenites spp. in counts.

Tetracolporopollenites spp.

See plate 8, fig.27,29,30.

TURMA: POROSES (Naumova 1937, 1939) Potonié 1960

SUBTURMA: MONOPORINES (Naumova 1937) Potonié 1960

Genus: PANDANIIDITES Elsik 1968.

Type species: Pandaniidites texus Elsik 1968, p.314, pl.15, fig.6.

Pandaniidites texus Elsik 1968.

Plate 9, fig.1-4.

1968 Pandaniidites texus, Elsik p.314, pl.15, fig.6.

Size. 12 specimens; 19.5 (23.0) 28.5 microns, pore diameter about 4 microns.

Comparison. Echigraminidites moravicus W. Kr. 1970 is more robust and has thicker spines.

Botanical affinity. Pandanus Palmae (Elsik 1968, p.314.)

Observed distribution. Generally rare in all formations from the Thanet Beds to London Clay, most consistent in the Woolwich and Reading Beds; fairly common at some levels in the Lignite and Woolwich Shell Beds; not recorded in the Oldhaven Beds.

Reported distribution. Palaeocene of Texas.

Genus: RESTIONIIDITES Elsik 1968.

Type species: Monoporopollenites hungaricus Kedves 1965, p.50-51, fig.1-6.

Restioniidites hungaricus (Kedves 1965) Elsik 1968.

Plate 9, fig.5.

1953 Inaperturopollenites incertus (Pf.& Th.) subsp. fossulatus; Th.& Pf. p.66, pl.5, fig.36.

1961 Restio sp. b. Ma Khin Sein, p.132-133, pl.8, fig.73, 74.

1966 Monulcipollenites confossus Fairchild; in Stover, Elsik & Fairchild p.3, pl.1, fig.3-6.

1968 Restioniidites hungaricus (Kedves 1965) Elsik; p.313, pl.15, fig.13.

1968 Monoporopollenites hungaricus Kds. 1965; Gr.-Cav. p.73, pl.9, fig.4.

1971 Monoporopollenites sp. A. Machin, pl.2, fig.14.

1977 Milfordia hungarica (Kedves 1965) W. Kr.& Vanh; W.Kr.& Vanhoorne, p.24, pl.11, fig. 17-18.

Description. Pollen grains oval, frequently folded; monoporate, aperture generally oval, between 4-5 microns long and 1.5-3 microns wide, a weak annulus often present although, in a few specimens, the aperture margin is ragged. Exine 1 - 1.5 microns thick, endexine and ektexine of equal thickness; ornament foveolate, pits less than 1 micron in diameter and irregularly distributed.

Size. 7 specimens; 32.0 (35.0) 40.0 microns diameter.

Comparison. Elsik describes the aperture as monoporate or "monulcoid", it is never as elongate as the monocolpate aperture of Milfordia Erdtman 1960. R. minimus differs only in its smaller size, less than 30 microns.

Botanical affinity. Restionaceae (Elsik 1968). Ladd (1977, p.13) describes this monoporate, annulate aperture type as "graminioid" and illustrates it in several extant pollen species from genera in the Restionaceae and in the Flagellariaceae. He suggests that some of the specimens found by Elsik could be restionaceous pollen or could represent members of the Flagellariaceae.

Observed distribution. Rare from Thanet Beds to London Clay (except Oldhaven Beds). May be fairly common in Woolwich Shell Beds. Less common than R. minimus. Rare to fairly common in the Bracklesham Beds at Alum Bay.

Reported distribution. This form has a wide geographic distribution in the Palaeocene; Belgium (Roche 1968), Paris Basin (Gruas-Cavagnetto 1968), Aquitaine ("Sparnacian", O.-Pierre 1970) and Texas (Elsik 1968); in the Eocene of Central Europe (Krutzsch 1970) and Hungary (Kedves 1974); but it is less common in the Oligocene and very rare in the Miocene of Central Europe (Krutzsch 1970).

Restioniidites minimus (W. Kr. 1970) Kedves 1974. Plate 9, fig.6.

1961 Restio sp. B Pallot, p.86, pl.13, fig.79.

1970c Milfordia minima W. Kr. p.76, pl.10, fig.7,8.

1974 Restioniidites minimus (W. Kr. 1970) Kds. p.26, pl.11, fig.1-3.

Size. 13 specimens; 22.5 (27.0) 29.5 microns.

Comparison. The smaller size distinguishes this from R. hungaricus, aperture structure and ornament are similar. Some of the grains included in Restio sp. b by Ma Khin Sein 1961, p.132, fall within the size range of R. minimus.
Observed distribution. Rare; present from Thanet Beds to London Clay (except Oldhaven Beds); may be fairly common at some levels in the Woolwich Shell Beds. Slightly more common than R. hungaricus. Rare to fairly common in the Bracklesham Beds at Alum Bay.
Reported distribution. General distribution in Europe from Eocene to Middle Oligocene, less common in younger beds, youngest occurrence Miocene (Krutzsch 1970).

Genus: SPARGANIACEAEPOLLENITES Thiergart 1937

Type species: Sparganiaceaepollenites polygonalis Thiergart 1937 p.307, pl.24, fig.11.

Comments. Several distinct taxa appear to have been placed in Sparganiaceaepollenites cuvillieri (Gr.-Cav.) Roche by various authors (see below). In the material examined from Southern England three distinct reticulate ornament patterns are recognised on large specimens of Sparganiaceaepollenites although there are transitional forms. The following species have been distinguished:

Sparganiaceaepollenites cuvillieri (Gr.-Cav. 1966) Roche 1968.

Plate 9, fig.10,11,14.

1966 Monoporopollenites cuvillieri Gr.-Cav. p.60, pl.2, fig.8-10, ?11, ?12.

1968 Monoporopollenites cuvillieri Gr.-Cav. 1966; Gr.-Cav. p.73, pl.9, fig.5,7,8.

cf.1968 Sparganiaceaepollenites (monoporopollenites) cuvillieri (Gr.-Cav. 1966) Roche; p.160, pl.2, fig.11, 12.

non 1976 Sparganiaceaepollenites cuvillieri (Gr.-Cav.) Roche 1968; Gr.-Cav. p.38, pl.1, fig.6,7.

non 1977 Sparganiaceaepollenites cuvillieri (Gr.-Cav. 1966) nov. comb. (sic); W. Kr. & Vanh. p.26, pl.12, fig.1-3.

Description. Grain spheroidal, monoporate. Exine is rigid, 1-2 microns thick, endexine and ektexine of equal thickness, reticulate. Muri duplibaculate to multibaculate, generally wider in the vicinity of the pore, bacula generally indistinct. Lumina are irregular shapes, 1 - 2.5 microns long with no obvious differentiation of lumina size away from the pore (as occurs in S. cf. cuvillieri).

Size. 32 microns; one specimen.

Comments. Similar to S. cf. cuvillieri in the presence of multibaculate muri and in the general rigidity of the exine but it differs in the absence of large lumina opposite the pore. There are probably gradations between this form and S. cf. cuvillieri . Although Gruas-Cavagnetto (1976, pl.1, fig.6,7) illustrates specimens of S. cuvillieri with larger lumina opposite the pore, her description and illustrations of the holotype (1966, pl.2, fig.7-10) show an even reticulation over the whole surface. I have excluded from S. cuvillierii s.s. specimens which show a marked increase in mesh size.

Observed distribution. Rare in the Woolwich facies of the Woolwich and Reading Beds.

Reported distribution. Common in the Sparnacian of the Paris Basin, France (Gruas-Cavagnetto 1966, 1968), present in the Woolwich Beds at Swanscombe (Gruas-Cavagnetto 1970).

Sparganiaceaepollenites cf. cuvillieri
Plate 9, fig.7,9,13,16.

1973 Sparganiaceaepollenites (monoporopollenites) cuvillieri (Gr.-Cav. 1966) Roche 1968; Roche, p.70, pl.5, fig.22,23, non fig.24.

1977 Sparganiaceaepollenites cuvillieri (Gr.-Cav. 1966) nov. comb. (sic); W. Kr.& Vanh. p.26, pl.12, fig.1-3.

Description. Pollen grains spherical to oval; monoporate, pore margin indistinct. Exine rigid, 2 microns thick. Endexine and ektexine of equal thickness. Ektexine with a reticulate ornament, muri up to 2 microns wide, duplibaculate to multibaculate, occasionally with small lacunae within the walls (plate 9, fig.7,13). Lumina around the pore are small, generally less than 2 microns; on the opposite hemisphere they are larger, more irregular, up to 4 microns long and

separated by wide, multibaculate muri. The bacula which support the muri are distinct, giving the grains a granular appearance in some focal planes (plate 9, fig.7).

Size. Diameter 33 microns. One specimen.

Comments. Krutzsch and Vanhoorne's specimens show the marked difference in lumina size which is typical of the London Basin material. It is probable that there are forms with less pronounced differences in lumina size which are transitional to S. cuvillieri s.s.

Botanical affinity. Similar pollen occurs in the Sparganiaceae and Typhaceae although the latter occurs more frequently in tetrads. Punt (personal communication September 1972) remarked that the specimen illustrated in plate 9, fig. 7,9,13,16 is very similar to modern Sparganium emersum (syn. S. simplex).

Observed distribution. Very rare. Occasionally present in Woolwich and Reading Beds, Woolwich facies, especially the lignite horizon at Shorne Wood.

Recorded distribution. Upper Landenian of Belgium, (Roche 1973, Krutzsch and Vanhoorne 1977).

Sparganiaceaepollenites magnoides Krutzsch 1970a

Plate 9, fig.8,12,15, plate 10, fig.1,2, cf.3.

1970c Sparganiaceaepollenites magnoides W. Kr., p.82, pl.13, fig.14-23.

1976 Sparganiaceaepollenites cuvillieri (Gr.-Cav. 1966) Roche 1968; Gr.-Cav. pl.1, fig.6,7.

Description. Grains spheroidal to oval, monoporate, with a reticulate ornament which is markedly coarser opposite the pore. Exine thin, 1.5 microns, frequently showing secondary folding; endexine 0.5 microns, ektexine 1.0 microns. Ornament is distinctive; lumina near the pore are small, 1.0-1.5 microns, separated by duplibaculate muri up to 1 micron wide. On the opposite hemisphere lumina are noticeably larger, of irregular shapes, averaging 2.5 microns but often up to 5 microns; muri are usually narrow, irregular in width, simplibaculate or duplibaculate, only rarely multibaculate. The bacula which support the walls are usually clear.

Size. Diameter 29.5 (40.5) 48.0; 30 specimens.
Comparison. The exine of S. cf. cuvillieri is generally more rigid and has much wider multibaculate muri on the surface opposite the pore. S. retibaculus W. Kr. & Vanh. 1977 is larger (60-75 microns) and is more obviously multibaculate, although its ornament appears transitional between S. magnoides and S. cf. cuvillieri. Other species seen in the present material are either simplibaculate or lack the marked differences in lumina size typical of this species.
Botanical affinity. Probably Sparganiaceae.
Observed distribution. This is the most common of the large Sparganiaceaepollenites species present in the London Basin. Generally rare, most consistent in the Woolwich facies of the Woolwich and Reading Beds, particularly the lignite horizon at Shorne Wood where it may be very common (JL 865, JL 867). Also present in the London Clay at Alum Bay.
Reported distribution. See Krutzsch 1970a.

Sparganiaceaepollenites reticulatus (Dokt.-Hrebn. 1960) Krutzsch & Vanhoorne 1977.
Plate 9, fig.17-19.

1961 Monoporopollenites sp. C Pallot, p.90, pl.15, fig.87.
1971 Monoporopollenites sp. C Machin, pl.2, fig.18.
1976 Undescribed monoporate pollen, Martin, pl.27, fig.4,5.
1977 Sparganiaceaepollenites reticulatus (Dokt.-Hrebn. 1960) W. Kr. & Vanh. p.25, pl.11, fig.19-21.

Description. Grains spheroidal, monoporate with an annulus, and occasionally an operculum (Martin 1976, pl.27, fig.4,5 and pl.9, fig.17 herein). Pore clearly defined, diameter about 2 microns. Exine thin, about 1 micron, with a delicate, reticulate ornament. Bacula present only where muri join; bacula less than 1 micron high; muri less than 0.5 microns wide; lumina adjacent to the pore about 1 micron, over the rest of the grain varying from 1-2 microns.
Size. 20.0 (23.5) 28.0 microns; 5 specimens.
Comments. The forms described by Krutzsch & Vanhoorne 1977, p.26 are slightly larger, 30-40 microns, but are otherwise identical.

The presence of an annulus is not typical of Sparganiaceaepollenites Thiergart. However, these specimens

differ from the monoporate genus Aglaeoreidia (Erdtman) Fowler 1971 which does possess an annulus but generally has more bilateral symmetry and an ornament with sharply defined areas of coarse and fine reticulation.

The annulus and very delicate reticulation separate this from other species of Sparganiaceaepollenites.

Botanical affinity. Unknown.

Observed distribution. Occurs in the Woolwich facies of the Woolwich and Reading Beds, the lignite, Shell Beds and Striped Loams.

Reported distribution. Upper Eocene of the Isle of Wight (Machin 1971); Upper Landenian of Belgium, (Krutzsch & Vanhoorne 1977), Miocene of Poland (Doktorovitcz-Hrebnicka 1960).

Sparganiaceaepollenites sparganioides (Meyer 1956) Krutzsch 1970c

Plate 9, fig.20,21.

1961 Sparganiaceae:Typhaceae sp. D. Pallot; p.81-82, pl.21, fig.68.

1970c Sparganiaceaepollenites sparganioides (Meyer) W. Kr. p.80,84,85; pl.12; fig.1-36.

Comments. The present specimens are slightly smaller than those of Krutzsch (1970c) but are otherwise identical. The imperfect reticulum has very irregular, often elongate, lumina; muri are clearly simplibaculate and sometimes appear discontinuous. The species is distinguished from S. polygonalis by the larger, more irregular reticulum and more obvious, simplibaculate muri; from Sparganiaceaepollenites reticulatus by the imperfect reticulum; and from other species of Sparganiaceaepollenites by its smaller size.

Size. 21.0 (23.5) 26.0 microns; 20 specimens.

Observed distribution. Present in the Woolwich facies of the Woolwich and Reading Beds, especially the lignite at Shorne Wood and in the Woolwich Shell Beds.

Reported distribution. Oligocene of the Isle of Wight, (Pallot 1961); Middle Oligocene to Miocene of North Central Europe, (Meyer 1956, Krutzsch 1970).

Sparganiaceaepollenites sp. A sp.nov.
Plate 10, fig.5.

Description. Pollen grains spheroidal, frequently with secondary folding. Monoporate, with pore diameter up to 7 microns. Exine 1-1.5 microns thick; endexine smooth, 0.5 microns, ektexine up to 1 micron thick. Ornament reticulate, muri about 0.5 microns wide, simplibaculate to duplibaculate but the bacula are indistinct. Lumina irregular, sometimes elongate, ranging from 0.5-2 microns, large and small lumina irregularly distributed over the surface.
Size. 31.5 (35.0) 38.5 microns; 5 specimens.
Typical specimen. Plate 10, fig.5; JL 865b;4151125; size 35.0 microns. Locality; Lignite horizon within Woolwich and Reading Beds at Shorne Wood, Kent, GR:TQ 67306980.
Comparison. Differs from S. cf. cuvillierii and S. magnoides since there is no differentiation into areas of large and small lumina and clear bacula are absent. Distinguished from S. cuvillierii by its narrower muri and less rigid exine.
Botanical affinity. Probably Sparganiaceae.
Observed distribution. Rare in the Woolwich facies of the Woolwich and Reading Beds and in the London Clay.

SUBTURMA: DIPORINES (Naumova 1937) Potonié 1960

Genus: DIPORITES Van der Hammen 1954
Type Species: D. grandiporus Van der Hammen, p.91, pl.6, fig. lower right.

Diporites iskaszentgyorgyi Kedves 1965.
Plate 10, fig.6.

1968 Diporites iskaszentgyorgyi Kds. 1965; Gr.-Cav., p.75, pl.8, fig.24.
1974 Diporites iskaszentgyorgyi Kds. 1965; Gr.-Cav., pl.3, fig.1.
1976a Diporites iskaszentgyorgyi Kds. 1965; Gr.-Cav., pl.5, fig.7,11,18.

Botanical affinity. Burmanniaceae (Dictyostega), Gruas-

Cavagnetto 1976a.

Observed distribution. Recorded only from Alum Bay; London Clay (Division C-D) and Bracklesham Beds. Absent from the Woolwich and Reading Beds throughout the London Basin.

Reported distribution. This form is stratigraphically useful. Kedves comments that the species occurs in Hungary only in the Sparnacian and reports it from the Sparnacian of the Paris Basin. Gruas-Cavagnetto (1976a) records it from the Lower Bagshot Beds, Bournemouth Freshwater Bed and Fisher Beds III and V.

SUBTURMA: TRIPORINES (Naumova 1939) Potonié 1960

Genus: COMPOSITOIPOLLENITES R. Pot. 1960.
Type species: Pollenites rhizophorus R. Pot. 1934b, p.94, pl.5, fig.25.

Compositoipollenites rhizophorus (R. Pot. 1934b) R. Pot. 1960 subsp. rhizophorus.

Plate 10, fig.7,9-11.

1934 * Pollenites rhizophorus R. Pot. p.94, pl.5, fig.25.
1953 Intratriporopollenites rhizophorus (R. Pot.) Pf. & Th. subsp. geiseltalensis Pf.: Th. & Pf. p.88, pl.10, fig.2-6, not fig.1.
1958 "rhizophoroide" Formen; W. Kr. p.521, pl.10, fig. 20-31.
1961 Intratriporopollenites rhizophorus (R. Pot.) Pf. & Th. subsp. geiseltalensis Pf.; Ma Khin Sein, p.256, pl.26, fig.285.
1977 Compositoipollenites rhizophorus (R. Pot. 1934b) R. Pot. 1960 subsp. rhizophorus; W. Kr. & Vanh. p.62, pl.26, fig.1-3.

Description. Pollen grains spherical, triporate with clear annuli. Exine 1.5 - 2 microns thick, tegillate with supra-tegillar spines 3.5 - 6 microns long and 1.5 - 2.5 microns in basal diameter. Exine clavate, tegillum links heads of clavae which produce a granular appearance in transmitted light (plate 10, fig.7,10). Scanning

electron micrograph (plate 10, fig. 11) shows a foveolate ornament in the surface of the tegillum, between the spines.
Size. (excluding spines) 23.5 (28.0) 35.0 microns; 20 specimens.
Comparison. C. rhizophorus subsp. burghasungensis is distinguished by its more delicate, shorter spines. C. rhizophorus subsp. giganteus Roche 1968 and C. rhizophorus subsp. iodesoides W.Kr. & Vanh. 1977 are both larger with robust, long (6 - 8 microns) spines.
Botanical affinity. Not Compositae. Probably Icacinaceae, genus Iodes (Krutzsch 1961, p.328).
Observed distribution. It occurs throughout the Woolwich and Reading Beds and is commonest in the Reading area (9.6% in NB 1). Present also in the Thanet Beds (rare), the Oldhaven Beds (OG 27, OG 22) and the London Clay.
Recorded distribution. Krutzsch 1970, p.335 reports C. rhizophorus s.l. from the early Palaeocene to the late Eocene (Pg.-zone 3ab - 18). It occurs in the Upper Landenian of Belgium (Roche 1968, W. Kr.& Vanh. 1977). Ma Khin Sein (1961) reports it from the early Eocene of the Isle of Wight.

Compositoipollenites rhizophorus (R. Pot.) R. Pot. 1960 subsp. burghasungensis Mürr.& Pf. ex Th.& Pf.1953.
Plate 11, fig.1,2.

1951 "Burghasungen"-Typus Mürr.& Pf., pl.5, fig.33.
1953 Intratriporopollenites rizophorus (R.Pot.) Th.& Pf. subsp. burghasungensis Mürr.& Pf.; Th.& Pf., p.88, pl.9, fig.126-128, 131, 132.
1961 Iodes sp. Ma Khin Sein, p.205, pl.19, fig.202.
1977 Compositoipollenites rhizophorus burghasungensis Mürr. & Pf.; W. Kr. & Vanh., p.62, pl.26, fig.4-7.
1980 Malvacipollis sp. Frederiksen pl.1, fig.36,37,38.

Description. Pollen grains spherical, triporate with clear annuli. Exine thin, about 1 micron, tegillate; the tegillum links heads of clavae which forms the columellate layer. Tegillate structure not always discernable. Supra-tegillar ornament of delicate spines and occasional granules; spines narrow-based, 1 micron or less, height always less than 3 microns, usually 2-2.5 microns.
Size. (excluding spines) 23.5 (25.5) 29.5 microns; 7 specimens

Comparison. The size of this subspecies overlaps with that of C. rhizophorus ss., however the more delicate spines distinguish C. rhizophorus subsp. burghasungensis. Transitional specimens do occur.

Botanical affinity. Probably Icacinaceae, closer to Iodes than C. rhizophorus. Ma Khin Sein (1961, p.205) considered her specimens to agree with recent Iodes ovalis and I. vitense from China, except for their slightly curved spines.

Observed distribution. Generally rare, less common than C. rhizophorus ss.

Reported distribution. Upper Landenian of Belgium (Roche 1968, and Krutzsch & Vanh. 1977); late Eocene to early Oligocene (Thomson and Pflug 1953).

Compositoipollenites rhizophorus (R. Pot.) R. Pot. 1960 subsp. minimus Roche 1968.

Plate 11, fig. 3.

1968 Compositoipollenites rhizophorus (R. Pot.) Pot. subsp. minimus Roche, p.164, pl.2, fig.22-24.

1977 Compositoipollenites minimus W. Kr. & Vanh.; p.63, pl.26, fig.23-24.

1980 Malvacipollis sp. Frederiksen pl.1, fig.34,35.

Description. Pollen grains spherical, triporate with clear annuli; indistinct colpi may be present. Exine thin, about 1 micron, thickening to 2-3 microns at the pores. Ornament of very delicate spines, up to 1.5 microns high, generally 1 micron or less in basal diameter.

Size. 17.5 (19.0) 21.0 microns; 4 specimens.

Comparison. It differs from the other subspecies of C. rhizophorus in the combined features of small size and delicate ornament.

Botanical affinity. Uncertain.

Observed distribution. Generally rare, fairly common in the Reading facies of the Woolwich and Reading Beds (PK 20).

Reported distribution. Upper Landenian of Belgium (Roche, 1968; W. Kr. & Vanh. 1977 (Pg-zone 11).

?Compositoipollenites sp.

Plate 11, fig.4,5,9,10.

1968 Indeterminé no. 2 Gr.-Cav. p.78, pl.9, fig.16,17.

cf. 1977 Compositoipollenites fsp. A W. Kr. & Vanh. p.63, pl.26, fig.21.

Description. Aperture type indeterminate, possibly inaperturate. Grains spherical to oval, frequently folded. Exine thin, about 1 micron, with an ornament of closely spaced conical spines, 1.5-2 microns high and with similar basal diameter. In some specimens exine appears intragranular intrabaculate.

Size. 17.5 (21.0) 29.0 microns; 20 specimens.

Comparison. Indeterminé no. 2 Gr.-Cav. appears to be identical. Krutzsch and Vanhoorne's specimens are considerably larger (35-40 microns) but have the same wall structure, ornament and obscure apertures; they are certainly closely related to the present material.

Species of Compositoipollenites ss are characterised by prominent pores and therefore differ from this form.

Botanical affinity. Unknown.

Observed distribution. Rare through the Woolwich and Reading Beds, most persistent in the Shell Beds, also present the London Clay at Alum Bay, becoming fairly common in horizons transitional to Bracklesham beds (AB 63, AB 64).

Reported distribution. Gruas-Cavagnetto 1968 reports this form as present in low percentages in the Sparnacian of the Paris Basin.

Genus: INTRATRIPOROPOLLENITES Pf. & Th. 1953.

Type species: Intratriporopollenites instructus (R. Pot. & Ven.) Pf. & Th. 1953, p.87, pl.10, fig.21.

Intratriporopollenites microreticulatus Mai 1961.

Plate 11, fig.6,7.

1961 Intratriporopollenites microreticulatus Mai, p.64, pl.10, fig.6-7, (ex. W. Kr. 1958, pl.9, fig.23a,23b).

Size. 19.5 (26.0) 36.0 microns; 10 specimens.

Comparison. Most grains are smaller than those described by Mai (1961, p.64, 28.0-38.5 microns), but are otherwise identical. The smooth outline and micro-reticulate structure

with lumina c.0.5 microns diameter, discernible only at high magnifications, distinguishes this from other species.

Botanical affinity. Tiliaceae.

Observed distribution. Rare, present in the Woolwich and Reading facies of the Woolwich and Reading Beds and in the London Clay.

Reported distribution. Rare in the middle Palaeocene (Pg.-Zone 7b), regular to frequent from middle Palaeocene-middle Eocene (Pg.-Zones 8-15), very rare in the upper part of the middle Eocene and late Eocene (Pg.-Zones 16-17) of Europe (Krutzsch 1970).

Intratriporopollenites pseudinstructus Mai 1961.

Plate 11, fig.8,11-14.

1961 Intratriporopollenites pseudinstructus Mai, pl.10, fig.19-23.

1968 Intratriporopollenites pseudinstructus Mai 1961; Gr.-Cav. p.58, pl.5, fig.14-17.

1970 Intratriporopollenites pseudinstructus Mai 1961; O.-Pierre, pl.11, fig.15a,15b.

Description. Grains oblate, rounded triangular with apertures in the centre of the sides, tricolporate, rarely tetracolporate. Colpi short, but usually obvious, reaching one-third of the way to the pole. Pores oval with polar extension, surrounded by clear endannuli. Commonly there is differential staining of the endexine at the polar extension of the pores. Apertures usually protrude slightly at the equator and occasionally show a separation of exine layers forming a vestibulum (pl.11, fig.14). The scanning electron micrograph shows a colpus underlain by a granular endannulus. Exine about 1.5 microns thick between the colpi, endexine and ektexine of equal thickness. Reticulate ornament clear, lumina 0.5-1.5 microns in diameter.

Size. 25.0 (31.0) 39.0 microns; ten specimens.

Botanical affinity. Tiliaceae.

Reported distribution. Lower Palaeocene to Lower Oligocene in Germany (Mai 1961), Sparnacian of the Paris Basin (Gr.-Cav. 1968), Upper Landenian of Belgium (Roche 1969).

Observed distribution. See Appendix 2.

Intratriporopollenites sp. A sp. nov.

Plate 11, fig.15,16,18,19.

Description. Pollen grains oblate, amb round to rounded triangular. Grains tricolporate or 4-colporate with apertures in the middle of the sides. Colpi short, reaching about one-third of the way to the pole, generally narrow, not always discernable. Pores oval, with polar elongation, (as long as the colpi); and clear endannuli up to 3 microns thick. Exine 1-1.5 microns thick between apertures, ektexine clavate, up to twice as thick as endexine. Reticulate ornament with simplibaculate muri, lumina less than 1 micron on one hemisphere, more irregular and noticably coarser over the other, 1-1.5 microns.
Size. 28.0 (30.5) 33.0 microns; 10 specimens.
Typical specimen. Plate 11, fig.15,16,18; JL 865a; 401990; 32.0 microns. Locality, lignite horizon within the Woolwich and Reading Beds at Shorne Wood, Kent. GR:TQ 673698.
Comparison. Wall structure is the same as in I. pseudinstructus but the coarser reticulum over one hemisphere distinguishes this species. I. megainstructus W. Kr. & Vanh. 1977, pl.25, fig.7,8, has similar variations in lumina size but is considerably larger, 50 microns.
Botanical affinity. Probably Tiliaceae.
Observed distribution. Rare, irregular occurrence in all facies of the Woolwich and Reading Beds and in the London Clay, Divisions B,C at Alum Bay. Not recorded at Pegwell Bay or Oldhaven Gap.

OTHER SPECIES:

Intratriporopollenites sp.
See plate 11, fig.17.

Size. 3 specimens; 25.0, 28.5, 34.0 microns.
Comparison. This differs from the species of Intratriporopollenites listed above in the combination of weak annulus, very thin exine and the ornament of an imperfect reticulum.

MOMIPITES GROUP

Several generic names are in use for small pollen grains attributed to the primitive Juglandaceae. The pollen is triatriate, triangular in outline with concave to convex sides, and may have exine thinnings, folds or thickenings of various patterns. The family appears to have been more diverse in North America than in northwest Europe during the early Tertiary but occurs abundantly in the Woolwich and Reading Beds in the London Basin and at comparable horizons in France (Gruas-Cavagnetto 1968).

The group as a whole has been reviewed in three recent papers (Nichols 1973, Frederiksen & Christopher 1978 and Nichols & Ott 1978) and considerable taxonomic revision has been made. All three papers point to the close morphologic and phylogenetic relationships between species of the primitive Juglandaceae but, as yet, there is no general agreement on which morphological features should be used to define genera.

Momipites was created by Wodehouse in 1933 for spheroidal or oblately flattened triporate pollen grains, somewhat triangular in outline, closely similar to extant Momisia and Corylus. More recently the genus has been interpreted in several different ways. Stanley (1965) and Leffingwell (1971) consider Momipites to lack any kind of exine thinning over the poles. In contrast Nichols's emendation of Momipites (1973) broadens the genus to include species which possess a variety of patterns of exine thinnings, thickenings and folds. (I consider most of these features to be more characteristic of the genera Maceopollipollenites Leffingwell 1971, Platycaryapollenites Nagy 1969, or Plicatopollis Krutzsch 1962 see below). Frederiksen & Christopher (1978) exclude from Momipites those species with multiple thin spots or with triradiate folds and thickenings (typical of Maceopolipollenites and Plicatopollis respectively in this study). They include forms without thinned exine or with a thinned area (simple or ring-like) over one or both poles. This interpretation is much closer to Wodehouse's original definition.

The following genera are used in this study, their characteristics are discussed below.

1) Momipites Wodehouse 1933
2) Maceopolipollenites Leffingwell 1971
3) Platycaryapollenites Nagy 1969
4) Plicatopollis Krutzsch 1962

In the counts individual species have been distinguished wherever possible but most samples also contain poorly orientated or corroded grains of this general type which could not be identified with certainty. These are all included in a single "Momipites"-group which includes specimens from all four of the above genera and probably corresponds to the Momipites-Plicatopollis-Platycaryapollenites complex of Frederiksen (1979).

Genus: MOMIPITES Wodehouse 1933
Type species: Momipites coryloides, Wodehouse 1933 p.511, fig. 43.

Comments. According to the diagnosis (Wodehouse 1933, p.511) this genus includes spheroidal, or oblately flattened, triporate pollen grains somewhat triangular in outline. Wodehouse makes no mention of thinnings in the exine but comments on the close similarity of M. coryloides to Momisia and Corylus (which lack exine thinnings) and states that it differs from recent Engelhardtia spicata only in its larger size. The latter however may have a large, simple, polar thinning (see Stone & Broome, 1975, fig.10).

I have included in Momipites only small, triatriate pollen with either a simple polar exine thinning or without any exine thinning. Forms with a ring-like polar thinning or with multiple circular thinnings are placed in Maceopolipollenites.

Momipites coryloides Wodehouse 1933
Plate 11, fig. 20,21.

1933 Momipites coryloides Wodehouse, p.511, fig.43.
1978 Momipites coryloides Wodeh.; F.& C., p.128, 129, pl.1 fig.1.

Comments. Some of the specimens recorded have a large thinning over one pole but this is not always present.
Size. 10 specimens; 21.5 (26.5) 30.5 microns.
Comparison. Momipites strictus F.& C. 1978 is very similar and is difficult to separate, it is characterised by straight rather than convex sides and by narrowly rounded corners. Maceopolipollenites tenuipolus has a ring-like rather than simple thinning around the pole but is not easy to separate when the thinning is poorly developed.
Botanical affinity. See above.
Observed distribution. Not separated from M. tenuipolus in counts. Comparatively rare but the M. tenuipolus group is present in small numbers in all formations except the Oldhaven Beds.
Reported distribution. Palaeocene and Eocene of North America.

Momipites quietus (R.Pot. 1934b) Krutzsch 1972
Plate 13, fig.1.

1934 Pollenites quietus R. Potonié, pl.4, fig.18.
1958 quietus-Gruppe W. Kr.; pl.8, fig.38-43.
1970a Momipites ex gr. quietus (R.Pot. 1931c) W. Kr.; W. Kr. p.346, pl.6, fig.133, pl.15, fig.149.
1974 Momipites quietus (R.Pot. 1934) W. Kr. 1972; Kedves p.49, pl.18, fig.13-15.
1976 Triatriopollenites engelhardtioides Roche 1973; Gr.-Cav. pl.6, fig.5, pl.10, fig.8.

Comments. This species is characterised by its small size and by its well-defined, straight-sided triangular outline. A simple exine thinning is occasionally present over one pole.
Botanical affinity. Engelhardtia (Gr.-Cav. 1976). The figure of recent Engelhardtia roxburghiana in Stone & Broome (1975, fig.1b) is very similar.
Observed distribution. Alum Bay only, Bracklesham Beds.
Reported distribution. Krutzsch 1970 records rare specimens from Pg.-zones 8-11 (middle Palaeocene to basal Eocene), it occurs regularly to frequently from Pg.- zone 12 (early Eocene) and is widespread in the middle Eocene.

Genus: MACEOPOLIPOLLENITES Leffingwell 1971

Type species: Maceopolipollenites triorbicularis Leffingwell 1971, p.30, pl.7, fig.5a,b.

Comments. The genus is distinguished from other small, triangular, triatriate genera by the presence of thinned exine over the pole in one hemisphere. Thinnings may be single; ring-like or Y-shaped, or multiple; circular or triangular, but not elongate (pseudocolpi) as in Platycaryapollenites Nagy 1969. There is no triradiate thickening or folding over the pole as in Plicatopollis Krutzsch 1962.

I have placed specimens with a single, large polar thinning in Momipites Wodehouse 1933, see below.

Maceopolipollenites rotundus Leffingwell 1971

Plate 11, fig.22,23.

1971 Maceopolipollenites rotundus Leffingwell pl.7, fig.7.

1978 Momipites ventrifluminis Nich.& Ott; p.102, pl.1, fig.9-14.

1978 Plicatopollis spp. of the P. triorbicularis type, Fr.& Ch.; pl.2, fig.1-4.

Description. Pollen grains oblate, rounded triangular in outline; triporate, with large, clear atria 7-10 microns wide and occasionally with slight annuli. Exine generally 1 micron or less between apertures, ektexine up to three times as thick as endexine. The species is characterised by three (rarely four) rounded exine thinnings grouped around the pole on one hemisphere.

Size. 10 specimens; 17.5 (23.0) 26.0 microns.

Comparison. Separated from M. triorbicularis by the convex rather than concave sides, and by its slightly larger size although their size ranges do overlap. (M. rotundus 24-34 microns, M. triorbicularis 20.2-26.4 microns).

Nichols and Ott, 1978 consider small variations in size (2-3 microns in the modal diameter of 50 specimens) to be significant in distinguishing species in "Momipites". They therefore recognise Momipites ventrifluminis as a separate species since it is smaller than Momipites rotundus (21-27 microns, with a modal diameter of 24.5 microns).

However, this method of separating species is not practicable since single specimens of intermediate size cannot be assigned to either species. I consider M. ventriflu-minis to be a junior synonym of M. rotundus.

Plicatopollis lunatus Kedves 1974 is superficially similar but is distinguished by the presence of triradiate "endoplicae" (whether thickenings or folds) which extend over one pole.

Botanical affinity. Primitive Juglandaceae. Leffingwell describes the pollen morphology of the genus as intermediate between that of modern Engelhardtia and Alfaroa and of Carya (1971, p.30).

Observed distribution. Irregularly distributed throughout the London Basin, from the Thanet Beds to the London Clay, most persistant in the Reading Beds at Pincents Kiln where it reaches 4.4% (PK20). Also present in the London Clay and Bracklesham Beds (4.4% in AB 70) at Alum Bay.

Reported distribution. Common in the Palaeocene of Wyoming (Leffingwell 1971, Nich.& Ott. 1978); and in the Danian - Ypresian equivalents of South Carolina (F. & C. 1978).

Maceopolipollenites tenuipolus (Anderson 1960) Leffingwell 1971.

1953 Triatriopollenites coryphaeus (R.Pot.) Th.& Pf. subsp. microcoryphaeus R.Pot.; Th.& Pf., p.80, pl.8, fig.10, 34 only.

1960 Momipites tenuipolus And., pl.7, fig.14.

1971 Maceopolipollenites tenuipolus (And.) Leffingwell, p.31, pl.7, fig.4.

1973 Momipites tenuipolus And.; Nichols, p.107, pl.1, fig.16-19 only.

1973 Maceopolipollenites tenuipolus; Tschudy, pl.1, fig.2.

1978 Momipites anellus Nich.& Ott; p.103, pl.1, fig.22-25.

1978 Momipites leffingwellii Nich.& Ott; p.103, pl.1, fig.27-30.

Comments. Only specimens with a ring-like exine thinning around one pole have been included in this species. Specimens with a single, large polar thinning have been placed

in Momipites coryloides. There is probably gradation between these two forms however and M. tenuipolus has been included in Momipites coryloides in counts.

I consider Momipites anellus and M. leffingwellii of Nichols & Ott to fall within the range of variation of Maceopolipollenites tenuipolus. Maceopolipollenites amplus Leffingwell is larger (29-37 microns) than M. tenuipolus (14-20 microns).

Botanical affinity. Primitive Juglandaceae (Leffingwell 1971).

Observed distribution. Comparatively rare in the London and Hampshire Basins. Included with Momipites coryloides in counts.

Reported distribution. Palaeocene in North America. Late Eocene to early Oligocene in Europe (Thomson & Pflug 1953).

Genus: PLATYCARYAPOLLENITES Nagy 1969

Type species: Platycaryapollenites miocenicus Nagy, p.474, pl.53, fig.25,26.

Comments. This genus comprises small triporate pollen grains characterised by "2 or 3 interwoven arcoid bands" (Nagy 1969). Frederiksen & Christopher (1978) expand Nagy's description by describing the apertures as atriate, lacking distinct annuli or labra and by making it clear that the arcoid bands are slits or elongated areas of thin exine (pseudocolpi). They consider that specimens have a general resemblance to the pollen of modern Platycarya but are considerably different in detail, particularly in the number and arrangement of the pseudocolpi. They suggest that fossil specimens which are morphologically similar to the pollen of modern Platycarya Sieb. & Zucc. should be placed in that genus. This view is also held by Elsik (1974), Leopold & MacGinitie (1972) and Tschudy (1973). However, I consider that the fossil genus Platycaryapollenites is more appropriate, particularly for specimens from the early Tertiary.

The genus Plicatopollis Krutzsch 1961 differs since the exine thinnings are shorter and they are usually

associated with triradiate thickenings or folds over the poles (Frederiksen & Christopher 1978).

Platycaryapollenites anticyclus (Krutzsch & Vanhoorne 1977) comb. nov.

Plate 13, fig.4,5,9.

1958 microcoryphaeus - Gruppe; W.Kr., p.518, 519, pl.8, fig.8,9 only.

1968 Groupe coryphaeus; Gr.-Cav., pl.4, fig.10,12 only.

1977 Platcaryapollis cf. anticyclus W.Kr. & Vanh.: p.45, pl.20, fig.17,18.

1977 Platycaryapollis anticyclus W.Kr. & Vanh.; p.45, pl. 20, fig.19,20,21.

Description. Pollen grains oblate, amb rounded triangular, triporate with clear intragranular atria, no labra or annuli. Exine about 1 micron thick, two-layered but the very thin inner layer (?endexine) is only occasionally discernible. Granular ornament visible in well-preserved specimens. Exine thinned over each pole in a distinctive pattern; one long arcuate thinning and one short, wedge-shaped thinning are present over one surface (as in P. platycaryoides, see plate 12, fig.2,3), the opposite surface has a horseshoe-shaped to triradiate thinning. Granular ornament is continuous across this thinned exine.

Size. 20 specimens; 15.0 (18.0) 21.0 microns.

Comparison. The species differs from P. platycaryoides only in the presence of a horseshoe-shaped to triradiate thinning on one hemisphere.

Observed distribution. Fairly common in the Woolwich facies of the Woolwich and Reading Beds, lignite horizon and Shell Bed.

Reported distribution. Present in the Sparnacian (lignitic sands) of the Paris Basin (Gr.-Cav. 1968), and in the earliest Eocene (Pg.-zone 11) of Belgium (W.Kr. & Vanh. 1977).

Platycaryapollenites platycaryoides (Roche 1969) comb. nov.

Plate 12, fig.1-7.

1953 Triatriopollenites coryphaeus (Pot.) Th.&Pf. subsp. punctatus (R.Pot.) Th.&Pf.; Th.&Pf. p.80, pl.8, fig.15,20,21, cf. fig.26,31,32 only.

1953 Triatriopollenites coryphaeus (Pot.) Th.&Pf. subsp. microcoryphaeus (R.Pot.) Th.&Pf.; Th.&Pf. p81, pl.8, fig.43,58,59 only.

1958 microcoryphaeus - Gruppe W.Kr. p.518,519, pl.8, fig.1-5, 7,11 only.

1968 Triatriopollenites fsp.1 - cf. Platycarya Gr.-Cav. pl.4, fig.7.

1969 Triatriopollenites platycaryoides Roche, p.135, pl.1, fig.19.

1973 Platycarya spp. Tschudy pl.2, fig.30,31 only.

1976 Triatriopollenites platycaryoides Roche 1969; Gr.-Cav. pl.1, fig.18.

1977 Platycaryapollis saxonis W.Kr. 1969; W.Kr.&Vanh. p.44, pl.20, fig.1-3.

1978 Platycarya sp. Nichols & Ott, pl.2, fig.14.

1978 Platycarya platycaryoides (Roche) Frederiksen & Christopher; F.&C. p.138, pl.3, fig.3,4,5,6.

Description.

General features: Pollen grains oblate, amb rounded triangular; triporate, pores meridionally elongated with clear intragranular atria, no labra or annuli. Exine 1-1.5 microns thick between pores, endexine thinner than ektexine, not always recognisable. Two exine thinnings (pseudocolpi) occur on each hemisphere, one an elongated arc, the other wedge shaped (see plate 12,fig.3). In flattened grains, in transmitted light, the pseudocolpi appear as three crossing arcs (plate 12, fig.2), a pattern similar to that in recent Platycarya (see Stone & Broome 1975 Fig.1a). Under the scanning electron microscope an ornament of small cones is clearly seen and continues across the exine thinnings (seen as depressions in plate 12, fig.3). With transmitted light the ornament appears granular but is only discernible in well-preserved specimens under high power.

Wall structure: Ultra-thin sections were made from small groups of P. platycaryoides and were examined with a transmission electron microscope. The detailed wall structure of the fossil P. platycaryoides is very similar to that of extant Platycarya strobilacea as illustrated by Stone & Broome (1975, Fig.2c). Plate 12, fig.4 shows a section through a complete pollen grain with three areas of thin exine separated by exine of normal thickness. There are three distinct wall layers; a thin, homogenous, inner layer (nexine of Stone & Broome); a middle, granular layer (endosexine); and an outer, homogenous layer (ektosexine, tectum). Both the endo- and ektosexine are about twice as thick as the nexine. In the pseudocolpi the nexine remains of normal thickness but both sexine layers thin considerably, this is entirely comparable with the exine structure in P. strobilacea (Stone & Broome 1975, Fig.2c). In the fossil material slender channels cross the tectum (plate 12, fig. 4,5). Stone & Broome report similar channels in several species of the Juglandaceae, particularly Alfaroa costaricensis (Fig.5b) and Oreomunnea pterocarpa (1975, Fig.4b). Both Platycaryapollenites platycaryoides and Platycarya strobilacea have an ornament of short cones which is continuous across the thin exine (1975, Fig.2c and plate 12, fig.4,5 herein).

Aperture structure: The apertures of the fossils are slightly different from those in P. strobilacea. As plate 12, figs.5,6,7 show, the nexine becomes segmented and disappears before reaching the pore, forming an atrium. In Platycarya strobilacea however, the nexine tapers to extinction near the pore without becoming segmented. A further difference is in the thickening of the granular endosexine in P. strobilacea (Fig.2f) while in the fossils the endosexine thins towards the pore. The absence of homogenous nexine near the pore in Platycaryapollenites platycaryoides may allow the granular endosexine to appear more prominent and probably accounts for the granular structure of the atria when seen in transmitted light.

Size. 100 specimens; 14.0 (18.0) 21.0 microns.

Comparison. This species is distinguished from others in the genus by the characteristic pattern of the pseudocolpi (as illustrated in plate 12, fig.2).

Botanical affinity. Juglandaceae, probably Platycarya (Roche 1969, Frederiksen & Christopher 1978, Nichols & Ott 1978).

Observed distribution. Very common to abundant in the Woolwich facies of the Woolwich & Reading Beds (the lignite horizon and the Woolwich Shell Beds); present in smaller amounts in the Reading facies and the London Clay; rare to fairly common in the Thanet Beds.

Reported distribution. Widespread distribution in western Europe from the Palaeocene to Miocene, particularly common in the Palaeocene of the Paris Bain (Gr.-Cav. 1968); present in North America, early Eocene (Sabinian stage) of Wyoming (Nichols & Ott 1978).

Genus: PLICATOPOLLIS Krutzsch 1962

Type species: Pollenites plicatus R. Potonié 1934b, p.55, pl.2, fig.19.

Comments. The diagnostic features of this genus, as defined by Krutzsch (1962, p.277) are the symmetrically arranged exine thinnings. "Plicen" i.e. exine thickenings or folds, are treated as less important and Krutzsch suggests they may even be secondary characters. The genus was reviewed by Nichols (1973) who placed most species in Momipites, and by Frederiksen & Christopher (1978) who placed greater emphasis on the presence of triradiate polar structure and recognised four distinct morphological types within the genus:

1) Forms with three thin spots but no obvious thickened triradiate structures over the pole, e.g. specimens of the Plicatopollis triorbicularis type. I include these in Maceopolipollenites rotundus Leffingwell.

2) Forms with triradiate structures but no apparent thin spots e.g. Plicatopollis cretaceae. This form was not recorded in the present study.

3a) + 3b) Forms with both three thin spots on at least one hemisphere and with triradiate structures. This group is subdivided into a) plicate forms, i.e. the triradiate structure consists of folds or thickenings involving both the end- and ektexine, e.g. specimens of the Plicatopollis plicata type and b) endoplicate forms, i.e. the triradiate structure consists of folds in the endexine only, so that separation of the exine layers forms a narrow tube between endexine and ektexine (see Thomson & Pflug 1953, p.21, 35-37) e.g. specimens of Plicatopollis lunata type.

Frederiksen & Christopher attempt to differentiate between these two polar structures and conclude that, in forms with plicae (3a, P. plicata type), the exine is probably not thickened at all, but is merely folded. I agree with this interpretation. The London Basin material shows no evidence of polar thickening of the exine, although pronounced folds are present. The typical appearance of these grains seems to result from their distinct spherical shape (in contrast to the oblate pollen of other genera of primitive Juglandaceae). As the pollen is flattened the arcuate exine thinnings control the position of the polar folds (see Krutzsch 1958, pl.9, fig.10,12; Tschudy 1973, pl.2, fig.32,33 and Plicatopollis swasticoidus herein, plate 13, fig.2,3).

In contrast, grains with endoplicae (3b, P. lunata type), have aclear triradiate zone, usually darker than the surrounding exine, which Frederiksen & Christopher interpret as thickened exine rather than true endoplicae. I have not seen any definite specimens of this type in the material from southern England. However, Maceopollipollenites rotundus is relatively common and Frederiksen & Christopher (1978) do stress that intergradations are common between this (=P. triorbicularis) and the P. lunata

types in their material. They comment on the difficulty of deciding whether the polar exine is of normal thickness or is actually thickened in certain specimens.

Plicatopollis swasticoidus (Elsik 1974) nov. comb.

Plate 13, fig.2,3.

1969 Platycarya sp. Fairchild & Elsik, pl.37, fig.10.
1974 Platycarya swasticoida Elsik, p.94, pl.2, fig.30,31.
1977 Platycaryapollis trisolutionis W. Kr. & Vanh. p.44, pl.20, fig.4,5,6,7.
1978 Platycaryapollenites swasticoidus (Elsik) Frederiksen & Christopher; F. & Ch. p.136, pl.2, fig. 23-26.

Description. Pollen grains spheroidal, triangular in outline with convex sides; triporate, weak atria sometimes visible, no annuli. Exine smooth, about 1-1.5 microns thick, 2-layered; three arcuate exine thinnings present on each hemisphere usually reaching the equator near an aperture (plate 13, fig.2,3). No triradiate exine thickenings, but the long polar axis allows grains to fold adjacent to the pseudocolpi.

Size. 10 specimens; 16.5 (19.5) 21.5 microns.

Comparison. The spheroidal shape and pronounced polar folds present in this species are more characteristic of Plicatopollis than Platycaryapollenites. Frederiksen & Christopher (1978) note that this species intergrades with specimens of the P. plicata type, however, the arrangement of exine thinnings in P. swasticoidus is usually distinctive. Platycaryapollenites platycaryoides also has a different pattern of exine thinnings and is oblate rather than spheroidal.

P. swasticoidus has been included in Plicatopollis spp. (undifferentiated species) in counts.

Botanical affinity. Primitive Juglandaceae.

Observed distribution. Included in Pliacatopollis spp. (undifferentiated species); present in low percentages at most horizons studied, fairly common in the Woolwich Shell Beds.

Reported distribution. P. swasticoidus is common in the

early Eocene of South Carolina (Frederiksen & Christopher 1978) and Wyoming (Elsik 1974). Pollen of this general morphology, included in Plicatopollis spp., has been widely reported in the Palaeocene, Eocene and early Oligocene of northwest Europe (Thomson & Pflug 1953, as Triatriopollenites plicatus; Gruas-Cavagnetto 1968; Kedves 1974).

Genus: PISTILLIPOLLENITES Rouse 1962.
Type species: Pistillipollenites mcgregorii Rouse 1962, p.206, pl.1, fig.2.

Pistillipollenites mcgregorii Rouse 1962.
Plate 13, fig.6-8, 10,11.

1962 Pistillipollenites mcgregorii Rouse; p.206, pl.1, fig.2.

1966 Triporopollenites bullis Gr.-Cav. p.60, pl.3, fig.9, 10, 13-16.

1968 Pistillipollenites mcgregorii Rouse; Elsik p.638, pl.34, fig.9, pl.35, fig.1,2a,b,c,3a,b.

1968 Pistillipollenites bullis (Gr.-Cav. 1966); Gr.-Cav. p.76, pl.10, fig.1,2.

1970 Pistillipollenites macgregorii Rouse; Rouse & Srivastava pl.1-4, fig.1-25.

Comments. Elsik (1968) emended the genus to include tricolpoidate or tricolpoidorate forms. Gruas-Cavagnetto, 1968, p. 76, also mentions the presence of colpi. In the present material apertures are generally obscure, often hidden by elongate sculptural elements next to the apertures, no definite colpi were seen. The main scultural elements,gemmae, are very variable in number and in distribution over individual grains. Scanning electron micrographs of the London Basin material show a micro-verrucate ornament between the gemmae which is not resolvable with the light microscope (plate 13, fig.10,11),this is comparable to the ornament shown by Rouse & Srivastava (1970, e.g. pl.1, fig.7). However the baculate structure they describe is not discernible in my material.
Size. 30 specimens; 15.0 (21.0) 25.0 microns.
Botanical affinity. Uncertain. Rouse 1962 compares the ornament of P. mcgregorii with that of recent Rusbyanthus but comments that R. cinchonifolius (Erdt. 1952) has

tricolporate apertures. Elsik notes that the ornament in some genera of the Caesalpinaceae is similar. Gruas-Cavagnetto (p.76) comments that J.L.K. Warter 1966 found similar forms in the early Eocene of Mississippi which he related to Bauhinia (Leguminosae). Rouse & Srivastava (1970, p.291) conclude that the affinity of P. mcgregorii is uncertain.

Observed distribution. Not present in the Thanet Beds. Characteristic of the Woolwich facies of the Woolwich & Reading Beds; fairly common at some levels within the lignite horizon at Shorne Wood (JL 856,5.2%; JL 879, 4.4%) but not recorded in the Reading facies at the western end of the London Basin nor in the Woolwich Marine Beds at Oldhaven Gap. Occasionally present in the London Clay and Brackle-sham Beds at Alum Bay.

Reported distribution. The species has wide geographic distribution, occurring in Europe, U.S.S.R, Alaska, Western Canada and U.S.A. Except for a Cenomanian record in Oklahoma it has been recorded most commonly from the Upper Palaeocene to Middle Eocene (Rouse & Srivastava p.287). Elsik (pers. comm. 1972) remarks that Pistillipollenites sp. is seen in abundance only in the late Palaeocene to early Eocene in the Gulf Coast of North America; it occurs rarely in the middle Eocene but may be reworked there. In Central Europe (W.Kr. & Vanh 1977, p.59) it is present from the middle Paleocene to early Eocene (Pg.-zones 9-13b).

Genus: SUBTRIPOROPOLLENITES Thomson & Pflug 1953

Type species: Subtriporopollenites anulatus Th.& Pf. subsp. notus Th.& Pf.1953 p.85, pl.9, fig.49.

Subtriporopollenites anulatus (Pf.& Th. 1953) W.Kr. 1961 subsp. anulatus W.Kr.1961.
Plate 13, fig.17.

1958 anulatus - Gruppe W.Kr. p.518, pl.7, fig.41,42 only.

1970 Subtriporopollenites anulatus - Gruppe W.Kr. p.344, pl.13, fig.120.

Size. 24.5, 36.5, 39.0 microns, three specimens measured.

Comparison. This species is closest to Subtriporopollenites constans but differs in the thinner exine and absence of

verrucate ornament. Small forms, less than 20 microns (subsp. nanus) are transitional to S. constans.

Botanical affinity. Primitive Juglandaceae.

Observed distribution. Rare. Subspecies nanus rare in Thanet Beds, Woolwich & Reading Beds and London Clay.

Reported distribution. Subtriporopollenites anulatus - Gruppe (subsp. anulatus and nanus) present throughout the Palaeocene and Eocene of central Europe (Krutzsch 1970).

Subtriporopollenites anulatus (Pf.& Th.1953) subsp. nanus Th.& Pf. 1953.

See Plate 13, fig.16 and Krutzsch & Vanhoorne 1977, pl.21, fig.10-11.

Subtriporopollenites constans Pf. 1953 subsp. constans W.Kr. 1961.

Plate 13, fig.14,15.

1958 constans - Gruppe W.Kr. p.518, pl.7, fig.37-39.

1960 Subtriporopollenites constans subsp. constans Pf; W.Kr. in W.Kr., P. & S., pl.2, fig.66.

1970 Subtriporopollenites-constans-Gr. (kleinere Formen) W.Kr., p.345, pl.14, fig.132.

1973 Subtriporopollenites spissoexinus Roche subfsp. nanus; Roche p.65, pl.4, fig.43,44.

1973 Subtriporopollenites constans Pf. 1953 subfsp. constans W.Kr. 1961; Roche p.61, pl.4, fig.35-38.

1977 Subtriporopollenites constans Pf. 1953 subsp. constans; W.Kr.& Vanh., p.57, pl.22, fig.2-8.

Description. Amb circular to rounded triangular, some grains have a slight depression over one pole. Grains triporate, pores equatorial to subequatorial with atria usually clear and strongly intragranular, but occasionally indistinct. Exine 1.5 to 2.5 microns thick, ektexine twice as thick as endexine, lamellar with a granular structure and a verrucate to rugulate ornament. Verrucae range from 1-3 microns in diameter but are less than 1 micron high (see plate 13, fig. 14), rugulae predominate over the polar depression.

Size. 10 specimens; 19.5 (22.5) 26.0 microns.

Comparison. Specimens with a very weak, verrucate ornament and a smooth or granular outline are transitional to small specimens of Subtriporopollenites anulatus. The distinction between S. constans sl. and Triporopollenites undulatus Pf. 1953 is not clear, transitional forms, with equatorial pores do occur.

Botanical affinity. Primitive Juglandaceae (Krutzsch, 1961).

Reported distribution. Present in the ? Danian to Palaeocene of Hannover (Pflug 1953), the Thanetian to Cuisian of the Paris Basin (Kedves 1967, Gruas-Cavagnetto 1968), the Upper Montian and Upper Ladenian of Belgium (Roche 1967) and reported by Krutzsch (1970, as the S. constans group, smaller form) from the Palaeocene to Middle Oligocene of Central Europe, although he says that in the Upper Eocene and above this can hardly be separated from the S. anulatus group.

Subtriporopollenites constans Pf. 1953 subsp. magnus W.Kr. 1961

Plate 13, fig.18-23.

1960 Subtriporopollenites constans magnus W.Kr. in W.Kr., P.& S, pl.2, fig.67.

1968 Subtriporopollenites constans Pf. 1953 subfsp. magnus Kr. 1960 (sic); Gr.-Cav. p.55, pl.5, fig.6-8.

1970 Subtriporopollenites constans Pf. 1953 subfsp. magnus W.Kr. 1961; Kedves & Pardutz, p.568,569, pl.6, fig.1-6.

1973 Subtriporopollenites spissoexinus subfsp. spissoexinus Roche, p.65, pl.4, fig.34,40-42.

Comments. The morphology, structure and ornament are the same as in S. constans subsp. constans except for the larger size; exine is 1.5-3 microns thick, verrucae are 3-4 microns in diameter. It is interesting to compare the detailed wall structure seen in the present material at magnifications of 1000 with that shown in Kedves & Pardutz's transmission electron micrographs (1970, pl.6). With the T.E.M. the exine is seen to be composed of a comparatively

solid "sole" (cf. the endexine in plate 13, fig.22,23 herein). Outside this is a thick baculate layer, which is only recognisable as a granular texture in specimens viewed with the light microscope (pl.13, fig.20,23), although the T.E.M. shows the baculae to be irregularly arranged, but mainly radial (Kedves & Pardutz 1970, pl.6, fig.6). This baculate layer probably corresponds to the thick lamellar structure which forms the main part of the exine as seen with the light microscope (pl.13, fig.22,23). The outer wall layer is a smooth tectum with suprategillar verrucae (1970, pl.6, fig.4,5). The tectum cannot be distinguished with the light microscope but the verrucae are clear both in plan view and from the wavy outline of the grains (pl.13, fig.18,19). Kedves & Pardutz show that the sole is absent in the pore region and the baculate layer thickens (1970, pl.6, fig.6), this would account for the strongly intragranular atria seen in my material (e.g. plate 13, fig.21,23).

Size. 30.5 (33.5) 39.0 microns; 10 specimens.

Comparison. Differs from S.constans subsp.constans in its larger size; Triporopollenites undulatus and T. vadosus Pf. differ in the absence of atria but there may be transitional forms.

Botanical affinity. Primitive Juglandaceae (Krutzsch 1961).

Observed distribution. This is a distinctive element of the Woolwich facies of the Woolwich and Reading Beds although it is never common.

Reported distribution. Widespread throughout northwestern Europe from the Palaeocene to early Eocene in Westbrandenburg (Krutzsch et al. 1960), Central Europe (Krutzsch 1961), Paris Basin and Kent (Gr.-Cav. 1968, 1970), and Belgium (Roche 1973, Krutzsch & Vanhoorne 1977).

Subtriporopollenites magnoporatus (Pf.& Th. 1953) W.Kr. 1961 subsp. magnoporatus

Plate 14, fig.1,2.

1953 Intratriporo-poll. magnoporatus Pf.& Th.; Pf. pl.24, fig.68 only.

1958 magnoporatus Gruppe W.Kr. pl.7, fig.34,35, cf. fig. 32-33.

1968 Subtriporopollenites magnoporatus (Pf.& Th. 1953) Kr. 1960; Gr.-Cav. p.56, pl.5, fig.10.

1969 Subtriporopollenites magnoporatus (Pf.& Th.) W.Kr. 1961 subfsp. tectopsilatus; Roche fig.25.

1970 Subtriporopollenites magnoporatus Kr. 1960 subfsp. magnoanulus Roche 1967; Gr.-Cav. pl.1, fig.31.

1970 Subtriporopollenites magnoporatus magnoporatus (Th.& Pf.) W.Kr. 1961; W.Kr. p.344, pl.4, fig.89, pl.11, fig.67.

Description. Pollen grains triporate, annulate with large atria about 7 microns in diameter. Exine complex, composed of a thin endexine, about 0.5 microns thick, which does not reach the pore; and an ektexine comprising three layers; a thin homogenous (? foot) layer about 0.5 microns, which is not always distinguishable from the endexine; a distinct baculate layer between 0.5 and 1 micron thick; and a thin, smooth tegillum. At the pores the homogeneous ektexine swells to form an annulus about 2.5 microns thick, and the baculate layer thins above it (plate 14, fig.1). Pore diameter, about 2 microns.

Size. 28.0 (29.0) 31.5 microns.

Comparison. This form differs from Subtriporopollenites supracirculus in the annulate pores, its stronger development of baculae and its larger size. S. constans s.l. lacks annuli and has a lamellar exine.

Botanical affinity. Primitive Juglandaceae (Krutzsch 1961).

Observed distribution. Rare, present in the Woolwich facies of the Woolwich & Reading Beds.

Reported distribution. Danian to Middle Palaeocene (Pg.-zones 4-9), rare in Lower to Middle Eocene (Krutzsch 1970).

Subtriporopollenites subporatus W.Kr. 1961

Plate 14, fig.3.

1953 Intratriporopollenites magnoporatus Pf.& Th., p.86, 87, pl.9, fig.95,96 only.

1958 anulatus-Gruppe W.Kr. pl.7, fig.40,44 only.

1960 "Intratriporopollenites" subporatus Kr.; in W.Kr., Pschalek & Spiegler, pl.2, fig.63.

1961 Subtriporopollenites subporatus W.Kr; p.308, pl.2,

fig.39,40.

1968 Subtriporopollenites anulatus Pf. & Th. 1953 subfsp. anulatus Kr. 1960; Gr.-Cav. pl.5, fig.1.

1970 Subtriporopollenites subporatus W. Kr.; W. Kr. pl.4, fig.90, pl.11, fig.54, p.344.

1977 Subtriporopollenites subporatus W. Kr. subfsp. subporatus; W. Kr. & Vanh. p.47, pl.21, fig.1-9.

Description. Grains rounded triangular with three sub-equatorial pores and large granular atria. Exine complex, 2-3 microns thick; endexine thin, less than 0.5 microns; ektexine composed of several layers, an inner, homogeneous layer, a middle baculate layer and an outer thick, lamellar layer.

Size. 2 specimens; 25.5, 29.5 microns.

Comparison. This species differs from S. magnoporatus in the sub-equatorial position of the pores, in the absence of annuli and in the presence of a thick lamellar ektexine; S. constans subsp. magnus has a verrucate ornament; and the exine of S. anulatus is thinner.

Botanical affinity. Juglandaceae (Krutzsch 1961, page 309).

Reported distribution. Krutzsch 1970 reports it from Pg. zone 4-13b, early Palaeocene to early Eocene, although it is very rare from the late Palaeocene and early Eocene (Pg. zones 10-13b).

OTHER SPECIES:

Subtriporopollenites intrastructurus Krutzsch & Vanhoorne 1977.

See plate 13, fig.12,13 and W. Kr. & Vanh. 1977, pl.23, fig. 8-19; Triporopollenites microgranulatus Frederiksen 1980, pl.1, fig.23-29 is very similar but annuli are better developed.

Genus: TRIATRIOPOLLENITES Pflug 1953a

Type species: Triatriopollenites rurensis Pflug & Thomson p.79, pl.7, fig.95.

Triatriopollenites confusus Zaklinskaia 1963

Plate 14, fig.5-7,9.

1953 Trivestibulopollenites betuloides Pflug; Th. & Pf. pl.9, fig.27,28 only.

1967 Triatriopollenites confusus Zaklinskaia 1963; Bratzeva, pl.1, fig.F.

1969 Triatriopollenites costatus Norton, p.40, pl.5, fig.19.

1969 Paraalnipollenites confusus (Zaklinskaia) Hills & Wallace, p.141, pl.17, fig.1-8.

1974 Triporopollenites sp.1 (cf. Betula); McIntyre p.22, fig.13.

non 1974 Paraalnipollenites confusus (Zaklinskaia) Hills & Wallace 1969; McIntyre pl.22, fig.14.

Description. Pollen grains triporate, oblate to spheroidal; outline, rounded triangular with very convex sides and protruding apertures; secondary folding common. Triporate,very slight annuli occasionally recognisable; atria not usually discernible; distinct labra present. Exine scabrate, 1.0-1.5 microns thick between apertures, endexine and ektexine of equal thickness but not always discernible.

A ring-like exine thinning surrounds each pole leaving a circular island of darker (?thicker) exine (pl.14, fig. 5,7,9). There is considerable variation in the extent of secondary folding. This is pronounced in specimens typical of Paraalnipollenities confusus sensu Hills & Wallace (e.g. pl.14, fig.5,6) but there is gradation to specimens in which secondary folding is virtually absent (pl.14, fig.7,9). The latter appear transitional to Triatriopollenites subtriangulus although the exine is thicker than is usual in that species.

Size. 10 specimens (polar view) 17.0 (22.5) 27.0 microns.

Comments. I interpret the "arci" described by Hills and Wallace (1969) as secondary folds. Since specimens from the London Basin do not possess the arci or false pores described as diagnostic of the genus Paraalnipollenites (Hills & Wallace 1969) these specimens are retained in Triatriopollenites. They differ from species of Maceopolipollenites (which also may have a ring-like polar thinning) by their spheroidal shape and the presence of labra and from species of Plicatopollis by the circular, rather than triradiate, polar "thickening".

Botanical affinity. Unknown. ?Betulaceae.

Observed distribution. Characteristic of the Reading facies of the Woolwich and Reading Beds at the western end of the London Basin, generally common at Cold Ash Quarry and Pincents Kiln (PK 34), otherwise rare.

Reported distribution. Palaeocene of U.S.S.R. (Zaklinskaia, 1963); Basal Palaeocene (?Danian) of the Zeya-Bureya depression U.S.S.R. (Bratzeva, 1967); Maastrichtian and Palaeocene of Bathurst Island, arctic Canada (Hills & Wallace 1969); Maastrichtian of Canada (McIntyre 1974, as Triporopollenites sp.1).

Triatriopollenites subtriangulus (Stanley 1965) Frederiksen 1979.

Plate 14, fig.10-12.

1961 Corylus mullensis Simpson, pl.13, fig.14 only.

1965 Carpinus subtriangula Stanley, p.291, pl.43, fig. 13-16.

1967 Comptonia sp. Bratzeva, pl.1, fig.E.

1979 Triatriopollenites subtriangulus (Stanley) Frederiksen; pl.151, pl.2, fig.19-22.

Size. 10 specimens; 21.5 (26.0) 30.0 microns.

Comments. Specimens compare well with those illustrated by Stanley (1965) and Frederiksen (1979) although the thin polar area described by Frederiksen is not obvious. The exine is thinner than that in Triatriopollenites triangulus Frederiksen 1979 and has a more distinct granular structure than that species. The granules in the atria are also more distinct and occasionally are aligned in indistinct rows.

Botanical affinity. Stanley (1965) suggests affinity with Carpinus but Frederiksen (1979) considers that T. subtriangulus has more in common with Comptonia.

Observed distribution. Rare in the Woolwich and Reading Beds, most frequent at the western end of the London Basin.

Recorded distribution. Early Tertiary of Mull (Simpson 1961); Palaeocene (Fort Union Member) of South Dakota U.S.A. (Stanley 1965); Aquia and Marlboro Formations (Danian-Thanetian equivalents) in Virginia U.S.A. (Frederiksen 1979).

OTHER SPECIES:

Triatripollenites aroboratus Pflug 1953a

Not distinguished from Triporopollenites robustus Pflug (see below).

Triatriopollenites roboratus Pflug 1953a.

See plate 14, fig.8,15 and Pflug 1953a, pl.7, fig.71; Roche 1973, pl.4, fig.16; W. Kr. & Vanh. 1977, pl.19, fig. 3,4.

Triatriopollenites trangulus Frederiksen 1979.

See plate 14, fig.4 and Frederiksen 1979, pl.2, fig.23-26.

Genus: TRIPOROPOLLENITES Thomson & Pflug 1953.
Type species: Triporopollenites coryloides Pflug 1953a in Th. & Pf. p.84, pl.9, fig.20.

Triporopollenites plektosus Anderson 1960.

Plate 14, fig.13,14,16-18, cf.19,20.

1960 Triporopollenites plektosus Anderson, pl.27, pl.4, fig.14, pl.8, fig.16.

1961 Celtis Ma Khin Sein, p.167, pl.14, fig.141.

1973 Triporopollenites praetenuis Chmura, p.145, pl.32, fig.13.

cf.1974 Thomsonipollis sabinetownensis Elsik, p.98, pl.2, fig.47-49.

1976a Thomsonipollis cf. sabinetownensis Elsik 1974; Gr.-Cav. pl.1, fig.14,19,20.

1977 Triporopollenites kedvesi (Gr.-Cav. 1967) Gr.-Cav. 1976; Gr.-Cav. pl.6, fig.13,14.

Description. Outline circular to rounded triangular, frequently folded. Grains triporate, rarely 4-porate, one of more pores sub-equatorial pores annulate usually large for the size of the grain (2-3 microns in diameter). Exine thin, less than 1 micron to 1.5 microns in the middle of the sides, increasing to 2 microns at the pores. Most grains have a weak granulate to baculate structure which is most obvious at the pores under high magnification.

Size. 15.0 (19.5) 24.5 microns.

Comparison. The combination of thin, lightly structured exine and large, annulate pores distinguish this from other

small triporate pollen.

There seems to be a complete gradation from rounded grains with a distinct baculate structure (plate 14, fig.16 equivalent to T. sabinetownensis Elsik) through rounded grains in which the baculae are not obvious (plate 14, fig.14 equivalent to T. cf. sabinetownensis in Gruas-Cavagnetto, 1976a, pl.1, fig.14) to folded grains having a triangular outline and a weak granular to baculate structure visible at the pores (pl. 14, fig.17,18 equivalent to T. cf. sabinetownwensis in Gruas-Cavagnetto, 1976a, pl.1, fig.19,20.). Some of the specimens referred to Triporopollenites kedvesi by Gruas-Cavagnetto (particularly 1977, pl.6, fig.13,14) appear to belong here.

Botanical affinity. Chmura (p.145) notes that pollen similar to T. praetenuis is produced by some species of the Moraceae (eg. Humulus lupulus); by the subfamily Celtoideae (except Zelkova) of the Ulmaceae (especially Celtis sinensis var. japonica) and by the family Urticaceae, although the latter includes very small pollen (10-20 microns). Ma Khin Sein (1961, p.167) considers Celtis sinensis var. japonica to be the most similar recent type.

Observed distribution. Sporadic distribution in all formations examined except the Oldhaven Beds.

Reported distribution. Upper Cretaceous, Palaeocene and early Eocene in North America; Mexico, California and the Gulf Coast (Anderson 1960, Chmura 1973, Elsik 1974); Sparnacian of the Paris Basin (Gr.-Cav.1977); Eocene of the London Basin and the Isle of Wight (Ma Khin Sein 1961).

Triporopollenites robustus Pflug 1953a

Plate 14, fig.21-25.

1953a Triporopollenites robustus Pf.; Th.& Pf. p.82, pl.8, fig.140-148.

1953b Triporopollenites robustus; Pf. pl.22, fig.21-32.

1958 robustus - Gruppe W.Kr., pl.7, fig.45,46.

1972 Casuarinidites granulabratus (Stanley) Srivastava; Srivastava, pl.9, fig.2. fig.7, NON fig.11,12.

1973 Triporopollenites robustus (Mürr & Pf. 1951) Th.& Pf.

1953; Roche pl.4, fig.1,2,3.

1973 Triporopollenites spp. of the T. robustus type; Tschudy pl.2, fig.1,2.

1973 Triporopollenites sp. A (thin walled); Tschudy, pl.2, fig.3,4.

1978 Casuarinidites pulcher (Simpson 1961) Srivastava 1972; Frederiksen & Christopher, p.141, pl.3, fig.24.

1978 Casuarinidites sparsus; Fr.& Ch. p.142, pl.3, fig. 25-27.

1980 Casuarinidites pulcher (Simpson 1961) Srivastava 1972; Christopher et al. pl.1, fig.3,4.

Size. 20 specimens; 22.0 (28.5) 36.5 microns. Another (large) specimen measured 43.5 microns.

Comments. This species is very variable in wall thickness and aperture structure. It grades into Triatriopollenites aroboratus, which has distinct atria. I would include in T. robustus the specimens referred to Triatriopollenites aroboratus Pflug by Elsik (1968, pl.18, fig.10,11,13a) and Tschudy (1973, pl.2, fig.7). Specimens of both types have been included in T. robustus in counts.

In North American studies, pollen of this type has generally been placed in various species of Casuarinidites eg. Frederiksen & Christopher (1978). Frederiksen (1979) found the variation in Casuarinidites so great that he could not separate species but grouped them as Casuarinidites spp. (see also Christopher et al. 1980, p.109).

Botanical affinity. Casuarinaceae. Pollen of similar morphology is referred to Casuarina by Simpson (1961), Srivastava (1972) and Frederiksen & Christopher (1978).

Observed distribution. Present in small numbers in all formations examined from the Thanet Beds to Bracklesham Beds.

Reported distribution. Palaeocene-basal middle Oligocene in Central Europe (Thomson & Pflug 1953); Palaeocene and Eocene of U.S.A. (Elsik 1968, Srivastava 1972, Tschudy 1973). Casuarinidites pulcher, Midwayan-Claibornian (Danian-Lutetian equivalents) in the Gulf Coast U.S.A. (Christopher et al. 1980).

OTHER SPECIES:

Triporopollenites spp. undifferentiated.
See Plate 14, fig.26-28.

OTHER TAXA:

Caryapollenites triangulus (Pflug 1953a) Krutzsch 1961d.
See plate 15, fig.3,4 and Pflug 1953a, pl.9, fig.58, 60 (Subtriporopollenites simplex (R. Pot.& Ven.) Pflug subsp. triangulus Pflug 1953a); Kr.& Vanh. 1977, pl.20, fig.27, 28.
Comments. In counts C. triangulus is included with C. circulus and C. simplex in the group Caryapollenites spp.

Gallopollis minimus Gruas-Cavagnetto 1967.
See plate 15, fig.1,2,5-7 and Gr.-Cav. 1968, pl.10, fig.6-28 (subspp. minimus and concaviformis); W.Kr.& Vanh. 1977, pl.19, fig.24-26 (as Triatriopollenites concaviformis Zaklinskaja 1963).

Labrapollis labraferus (R. Pot. 1931b) Krutzsch 1968
See plate 15, fig.10 and W.Kr. 1958, pl.9, fig.24-25 (as labraferus-Gruppe); W.Kr. 1968, pl.1, fig.1-13.

Labrapollis globosus (Pflug) Krutzsch 1968.

Labrapollis cf. globsus, plate 15, fig.9 see W.Kr. 1968, pl.1, fig. 36,37.

Pentaporoites belgicus Krutzsch & Vanhoorne 1977.
See plate 15, fig.8 and W.Kr.& Vanh. 1977, p.38, pl.17, fig. 7-12; W.Kr. 1970, pl.9, fig.9; Gr.-Cav. 1977, pl.8, fig. 7. (See Chapter 5, p. 276).

Trivestibulopollenites betuloides Pflug 1953.
Included in Triporopollenites spp. in counts.

INFRATURMA: NORMAPOLLES Pflug 1953b.

Genus: INTERPOROPOLLENITES Weyl. and & Krieger 1953
Type species: Interporopollenites proporus Weyl.& Krieg. 1953, p.20, pl.1, fig. 34.

Interporopollenites proporus Weyl.& Krieger 1953
Plate 15, fig.12-14.

1967 Interporopollenites proporus Weyl.& Krieg; Góczán et.

al. pl.8, fig.11-15, p.469.

Size. 30.0, 33.0 microns, 2 specimens.

Botanical affinity. Unknown.

Observed distribution. Very rare. One specimen from the Reading facies of the Woolwich and Reading Beds at Knowl Hill; one specimen from the Thanet Beds, South Lambeth borehole.

Reported distribution. Species are poorly differentiated. The genus is reported from the late Cretaceous, early Campanian (Góczán et al. 1967); early-middle Palaeocene (Pg.-Zones 1-9) and early Eocene (Pg.-Zone 13) Krutzsch 1970, p.327.

OTHER TAXA:

Basopollis orthobasalis (Pflug 1953a) Pflug 1953b
See plate 15, fig.16,17 and Pflug 1953a, pl.6, fig.25; Pf.1953b, pl.21, fig.45; Krutzsch 1970, pl.7, fig.158.

Brosipollis striatobrosus (Krutzsch 1961) Krutzsch 1968a.
See plate 15, fig.11,15 and Krutzsch 1961d, pl.4, fig.91-93 (as Trivestibulopollenites striatobrosus); Krutzsch 1970, pl.12, fig.83; Gr.-Cav. 1976a, pl.3, fig.13,14.

Nudopollis endangulatus (Pflug 1953a) Pflug 1953b.
See plate 15, fig.20 and Pflug 1953a, pl.6, fig.37-42 (as Extratriporopollenites endangulatus); Pflug 1953b, pl.25, fig.22-24; Góczán et al. 1967, pl.11, fig.24-29; Roche 1973b, pl.1, fig.14.
Comments. Differs from N. terminalis in the presence of a longer pore-canal and in its non-granular atria.

Nudopollis terminalis (Pflug 1953a) Pflug 1953b.
See plate 15, fig.21-23 and Pflug 1953a, pl.6, fig.31. (as Extratriporopollenites terminalis); Pflug 1953b, pl.22, fig.1-3; Krutzsch 1958, pl.8, fig.25-30 (as terminalis-Gruppe); Krutzsch 1970, pl.12, fig.85 (as N. endangulatus subsp. endangulatus); Roche 1973b, pl.1, fig.15; Tschudy 1973, pl.2, fig.18,20 (as Nudopollis spp. of the N. terminalis type).
Comments. Distinguished from N. endangulatus by the presence of granular atria (see Pflug 1953a, p.71). Some specimens appear to have a vestibulum (plate 15, fig.21-23)

although Pflug considers them to be absent from this genus (1953b, p.108). N. endangulatus and N. terminalis have been recorded together, as Nudopollis spp., in counts.

Plicapollis pseudoexcelsus (Krutzsch 1958) Krutzsch 1961d.

See plate 15, fig.18,19 and Krutzsch 1958, pl.8, fig.34-37; Gr.-Cav. 1968, pl.3, fig.5-18.

Pompeckjoidaepollenites subhercynicus (Krutzsch 1954a) Krutzsch 1967.

See plate 15, fig.24,25 and Gruas-Cavagnetto 1968, pl.2, fig.27,30,31; Roche 1973, pl.3, fig.25,26,27; W. Kr. & Vanh. 1977, pl.14, fig.27-28.

Thomsonipollis magnificus (Th. & Pf. 1953) Krutzsch 1960b.

See plate 15, fig.26 and Góczán et al. 1967, pl.17. fig. 17-19; Srivastava 1972, pl.23, fig.12-15. (see Chapter 5, p.277).

Thomsonipollis magnificoides Krutzsch 1960b.

Trudopollis hammenii Roche 1969.

See plate 16, fig.1-3 and Roche 1969, pl.1, fig.23; Gruas-Cavagnetto 1974, pl.1, fig.4; Gr.-Cav. 1977, pl.1, fig. 2-4. (See Chapter 5, p.276).

Vacuopollis concavus (Pflug 1953a) Krutzsch 1960.

Vacuopollis semiconcavus Pflug 1953b.

See plate 16, fig.9 and Pflug 1953b, pl.20, fig.3-9.

Comments. The indistinct conclave described by Pflug (1953b, p.104) is not visible in my material. Not separated from V. concavus in counts. (See Chapter 5, p.275).

SUBTURMA: POLYPORINES (Naumova 1937) Potonié 1960

INFRATURMA: STEPHANOPORATI Van der Hammen 1954

Genus: REEVSIAPOLLIS Krutzsch 1970b

Type species: Pollenites triangulus Mamczar 1960, p.220, pl.14, fig.202.

Reevsiapollis triangulus (Mamczar 1960) Krutzsch 1970b.

Plate 16, fig.4,5.

1968 Indeterminé No.3 (Polyporopollenites silesiae Maz. 1960); Gr.-Cav. p.79, pl.10, fig.3,4.

1970 Bombacidites fsp; O.-Pierre p.110-112, pl.14, fig. 9a-12.

1970a Reevsiapollis triangulus (Mamczar 1960) W.Kr.; W.Kr. pl.6, fig.136.

1970b Reevsiapollis triangulus (Mamczar) W.Kr.; W.Kr. pl.5, fig.21,22, pl.6, fig.4-6.

Description. Pollen grains oblate, with three or more apertures, most commonly four or five. Apertures colporate, with short colpi; the endexine thickens towards the pores and in some grains separates from the ektexine to form a vestibulum, although it is rare to see a vestibulum at every aperture in a single grain. Ornament is reticulate, with luminae up to 1.5 microns over the poles but becoming finer towards the equator.

Size. 15 specimens; 13.5 (14.5) 17.5 microns.

Comparison. Although Gruas-Cavagnetto (1968, p.79) describes the ornament of her specimens as rugulate, a clear reticulation can be seen in her photographs. R. eocenicus Krutzsch has more pronounced apertures but the specimens of R. eocenicus illustrated by Krutzsch & Vanhoorne (1977, pl.28, fig.3,4,8) are very similar to my material.

Botanical affinity. Sterculiaceae, Reevsia (Krutzsch 1970b and Petrov & Drazheva-Stamatova 1972).

Observed distribution. Sporadic occurrence in all formations examined.

Recorded distribution. Wide geographical distribution through central Europe from Palaeocene to Pliocene (Krutzsch 1970a); early Eocene-Pliocene of U.S.S.R., Turkey, Poland (Petrov & Drazheva-Stamatova 1972).

Genus: STEPHANOPOROPOLLENITES Pflug & Thomson 1953.
Type species: Stephanoporopollenites (al. Pollenites) hexaradiatus Thierg. 1940 pl.12, fig.32-33 ex Pf.& Th. 1953 p.90.

Stephanoporopollenites hexaradiatus Pf.& Th.1953
subsp. semitribinae W.Kr. 1961d.

Plate 16, fig.8.

1961d Stephanoporopollenites hexaradiatus Pf.& Th. subsp.

semitribinae W.Kr., p.306, pl.2, fig.31-32.

1969 Stephanoporopollenites hexaradiatus subfsp. semitribinae W. Krutzsch 1961; Roche, p.134, fig.15,16.

1970a Stephanoporopollenites hexaradiatus subsp. semitribinae W.Kr. 1961; W.Kr. p.329, pl.5, fig.108, pl.9, fig.1.

1972 Stephanoporopollenites hexaradiatus semitribinae; Chat.& Roche p.254,256, fig.10.

Comparison. This subspecies is similar to S. hexaradiatus subsp. tribinae in having pores arranged in pairs with a marked equatorial constriction separating one pair from the next. The outline between the pores of each pair is straight in S. hexaradiatus subsp. tribinae but is concave in S. hexaradiatus subsp. semitribinae.

Observed distribution. Very rare. Recorded from the Thanet Beds of the South Lambeth borehole and Pegwell Bay and from the Woolwich and Reading Beds at Pincents Kiln (PK 20).

Recorded distribution. The subspecies ranges from Middle to Upper Palaeocene of boreal Central Europe (Pg.-Zone 7a-10, Góczán et al., 1967, p.505). Roche (1969) reports it from the Montian and Landenian of Belgium, and Kedves (1967a, p.16) from the Thanetian Zone II of the Puy-de-Dome.

Stephanoporopollenites hexaradiatus Pf.& Th. 1953 subsp. tribinae W.Kr. 1961d.

Plate 16, fig.6,7.

1961d Stephanoporopollenites hexaradiatus subsp. tribinae Krutzsch, p.307, pl.2, fig.33-34.

1967a Stephanoporopollenites hexaradiatus tribinae W. Kr; Kedves, p.15,16, pl.17, fig.1-8.

1969 Stephanoporopollenites hexaradiatus tribinae W. Kr. 1961; Kedves, p.391, pl.11, fig.33,34.

1969 Stephanoporopollenites hexaradiatus subfsp. tribinae W.Kr. 1961; Roche, p.134, fig.14.

1970a Stephanoporopollenites hexaradiatus tribinae W. Kr. 1961; W.Kr. p.329, pl.5, fig.123, pl.10, fig.29.

Botanical affinity. Unknown.

Observed distribution. Rare, recorded from the Thanet Beds of Pegwell Bay; present in the Woolwich and Reading Beds, the Woolwich Marine Beds at Oldhaven Gap, the Reading Beds at Pincents Kiln and the Woolwich Shell Bed at Charlton. Not recorded above the Woolwich and Reading Beds.
Recorded distribution. The subspecies is recorded from the middle Palaeocene to Lower Eocene in boreal Central Europe (i.e. Pg.-Zone 7b-13a, Góczán et al. 1967, p.505). Kedves (1967a, p.16) considers S. hexaradiatus s.l. to be resticted to the Palaeocene which he defines as extending to the top of the Thanetian. He records it in the Thanetian Zone II and III of the Paris Basin (1969) and the Thanetian of the Puy-de-Dome (1967a) but it is absent from the Sparnacian of the Paris Basin (Gr.-Cav. 1968) and from the Sparnacian of La Sennetiere, Loire Atlantique (O.-Pierre 1970). Roche reports it in the Landenian of Belgium (1969).

Genus: ULMIPOLLENITES Wolff 1934.
Type species: Ulmipollenites undulosus Wolff 1934, pl.75, pl.5, fig.25.

Ulmipollenites tricostatus (Anderson 1960) Frederiksen 1980

Plate 16, fig.14-17.

1960 Ulmoideipites tricostatus And., p.20, pl.4, fig.9-11, pl.6, fig.4,5, pl.7, fig.8.
1961 Planera mullensis Simpson, p.447, pl.14, fig.11 only.
1961 ?Phyllochlamys sp. Pallot, p.116, pl.20, fig.135.
1968 Triatriopollenites kedvesi Gr.-Cav.; Gr.-Cav. pl.4, fig.13 only.
1970 Triatriopollenites curryi Gr.-Cav., p.73, pl.1, fig.9,10.
1971 Ulmipollenites sp. Tschudy, pl.4, fig.17 only.
1977 Polyporopollenites eoulmoides W. Kr. & Vanh. p.64,65, pl.27, fig.11-14.
1977 Triporopollenites curryi (Gr.-Cav. 1970) Gr.-Cav. 1976; Gr.-Cav. pl.6, fig.15,16.
1980 Ulmipollenites tricostatus (Anderson 1960) Frederiksen

p.148, pl.1, fig.41.

Size. 13.00 (17.5) 22.5 microns.

Comparison. Specimens studied compare well with Anderson's illustrations; they are sub-triangular, have three depressed pores about 2 microns in diameter, and have a thin exine, (one micron) which thickens slightly towards the pores. Anderson describes "beaded ribs" which parallel the sides of the grain and join above the pores as characteristic of the species, although in some grains the ribs are reduced to poorly defined. Some of the specimens from the London Basin show clear beaded ribs (plate 16, fig.14,15) although there is a gradation to others which merely have slight folds (pl.16, fig.17). The strength of the ornament, verrucae and rugulae, ranges from barely perceptible to 1 micron high. Most grains show a clear depression over one pole, which may be a thinning in the exine; sculpture continues across it but is less well defined (see plate 16, fig.14,16).

Pallot illustrates a triporate form, ?Phyllochlamys sp. (Moraceae), which she says is very similar to recent Planera japonica but is larger, 14-16 microns, and has a less markedly scabrate exine (1961, p.116). This form compares well with the specimens of U. tricostatus with weak ornament.

T. curryi Gr.-Cav. 1970 is probably identical. The marked folds which run from one pore to the other (p.73, pl. 1, fig.9,10) are equivalent to the beaded ribs of U. tricostatus. Although Gruas-Cavagnetto describes the surface as smooth to chagrenate her illustrations show an undulating, verrucose ornament. In 1977, pl.6, fig.15,16 she refers her specimens to the Ulmaceae.

Botanical affinity. Ulmaceae. Anderson intended the genus Ulmoideipites to accommodate ulmaceaeous pollen including forms similar in morphology to Planera, Ulmus, Zelkova and Hemiptelia.

Observed distribution. Present throughout the London Basin from the Thanet Beds to the London Clay.

Reported distribution. Maastrichtian of Montana (Tschudy 1971); Uppermost Cretaceous to Palaeocene of New Mexico (Anderson 1960); Palaeocene of Mull (Simpson 1961); Palaeocene of the Paris Basin and Swanscombe, Kent (Gruas-Cavag-

netto 1968, 1970); Palaeocene of Belgium (Krutzsch & Vanhoorne 1977); Eocene to Oligocene of the Isle of Wight (Pallot 1961).

Ulmipollenites spp.

Comments. Grains included here are all small, with rounded triangular to circular outline and three or more equatorial pores with slight annuli. Exine is thin, with a polar depression and a verrucate to rugulate ornament. Arci are rarely present.

Size. 7 specimens; 13.0 (17.5) 22.0 microns.

Comparison. Similar forms are reported by Leopold in Penny (1969) as Ulmus or Zelkova type, pl.16-6, fig.29; by Fairchild & Elsik (1969) as Planera sp., p.85, pl.38, fig.40 and by Leffingwell (1971) as Ulmipollenites sp., pl.6, fig.6a,6b.

Observed distribution. Irregular distribution at all horizons studied in the London Basin and Alum Bay.

Reported distribution. Widespread throughout the Tertiary of northwest Europe and North America.

OTHER TAXA:

Alnipollenites trina (Stanley 1965) Norton 1969

See plate 16, fig.10,11 and Stanley 1965, pl.43, fig.4,5 (as Alnus trina); Norton & Hall 1969, pl.5, fig.20 and Frederiksen 1980, pl.1, fig.21,22 (as Alnus trina).

Alnipollenites verus Potonié 1934b

See plate 16, fig.12,13 and Polyvestibulopollenites verus (R.Pot.) Pflug 1953 in Th.& Pf. 1953, p.90, pl.10, fig.62-76; Polyvestibulopollenites eocenicus Krutzsch & Vanhoorne 1977, p.63, pl.27, fig.1-3; Polyvestibulopollenites quadratus W.Kr.& Vanh. 1977, p.64, pl.27, fig. 4-6.

?Nothofagidites sp.

See "Nothofagidites boureaui" Gruas-Cavagnetto 1977 (thesis), pl.8, fig.28 and Ch.& Gr.-Cav. 1968, pl.4, fig. 23 as Nothofagidites fsp.

Observed distribution. Very rare, isolated specimens in

the Alum Bay section, London Clay Division B,C; Bracklesham Beds (AB 57, AB 60 and AB 64).

Parsonidites britannicus Gruas-Cavagnetto 1976a.

See plate 16, fig.19,20 and Gr.-Cav. 1976a, pl.8, fig.9-12.

Observed distribution. Alum Bay, Bracklesham Beds, equivalent to Fisher Bed 1V.

Polyatriopollenites stellatus (R.Pot.& Ven. 1934) Pflug 1953b.

See plate 16, fig.18 and Pot. 1931, pl.2, fig.V47b (as Pollenites stellatus); Th.& Pf. 1953, pl.10, fig.85-94 (as Polyporopollenites stellatus); Pflug 1953b, pl.24, fig.47; Gr.-Cav. 1976a, pl.10, fig.3 (as Polyporopollenites stellatus).

INFRATURMA: PERIPORITI Van der Hammen 1956.

Genus: ERDTMANIPOLLIS Krutzsch 1962a

Type species: Erdtmanipollis pachysandroides W.Kr. p.281, pl.8, fig.1-8.

Erdtmanipollis sp.

Plate 16, fig.22.

Comments. Specimens found in southern England show the croton ornament, composed of radial rectangular elements and occasional larger wedge-shaped elements, typical of the genus. The number of pores is indeterminate.

Size. 27 microns, one specimen.

Comparison. Pachysandra cretacea Stanley 1965 (p.294,295, pl.44, fig.1-9) is very similar but specimens from the London Basin are too poorly preserved for direct comparison.

Botanical affinity. Gray and Sohma (1964) made detailed studies of recent Pachysandra and Sarcococca of the Buxaceae, two genera which are panporate and have croton ornament with both rectangular and wedge-shaped elements. They found fossil Erdtmanipollis to compare most closely with Pachysandra in terms of overall size and number of pores; they showed that most species of Pachysandra are over 42 microns in diameter while all except one species of Sarcococca

are less than 42 microns. In terms of size alone the London Basin material is therefore closer to Sarcococca. Observed distribution. Only two specimens were found in the present study, one from the Reading Beds at Pincents Kiln, (PK 4), and the second from the Woolwich Beds (marine facies) at Oldhaven Gap (OG 11). It is possible that the former may be reworked (either from within the early Tertiary or from the Cretaceous) since it did not accept Saffranin O stain in the same way as the Compositoi-pollenites spp. and Intratriporopollenites spp., both genera which occur fairly commonly at that locality and which appear to be of local contemporaneous origin. The presence of common Classopollis torosus (a characteristic Mesozoic species) is further evidence of reworking. Recorded distribution. Erdtmanipollis is now well known from the Upper Cretaceous and the Tertiary and has wide geographic distribution in North America, U.S.S.R. and central Europe. Dr. Linda Phillips (pers. comm. 1974) found a single specimen in the Tertiary volcanic province of the Scottish Western Islands which was associated with a temperate flora, of probable Palaeocene age.

It is interesting to note that Erdtmanipollis is always very rare; Gray and Sohma (1964) consider this scarcity to be due to an inability to enter the sediment rather than absence of the genus, or of low pollen production. They suggest that the tendancy of Pachysandra and Sarococca to grow on ravine slopes above small streams would lead to chance entry of pollen into depositional basins, and account for the sporadic fossil records which occur in the Cretaceous and Tertiary.

Genus: PERSICARIOIPOLLIS Krutzsch 1962

Persicarioipollis persicarioides Krutzsch 1966.

Plate 16, fig.21,25.

1966 Persicarioipollis persicarioides W.Kr; p.30, pl.4, fig.16-21.

1968 Persicarioipollis persicarioides Kr. 1966; Gr.-Cav. p.78, pl.10, fig.5,10.

Size. 2 specimens, 20.0, 26.0 microns.

Botanical affinity. Krutzsch (1966) lists several families which contain genera with similar ornament, of these the Polygonaceae, particularly Persicaria pro parte and Polygonum pro parte, are closest.

Observed distribution. Very rare, only three specimens were found in the Woolwich Shell Beds at Shorne Wood, and one from the Woolwich and Reading Beds in the Leaden Roding Borehole, Essex (LR 17).

Reported distribution. Gruas-Cavagnetto (1968, p.78) reports a single specimen from the Sparnacian of Sinceny. Krutzsch (1970) records the species from the middle Palaeocene (Pg - Zone 9), early Eocene (Pg-Zones 12-13) and middle Eocene (Pg-Zone 15) of Central Europe.

OTHER TAXA:

Periporopollenites spp.

See plate 16, fig.23.

INFRATURMA: DIPLAPERTURATE POLYPORINES Potonié 1966

Genus: INTERPOLLIS Krutzsch 1961d

Type species: Intratriporopollenites supplingensis Pf., in Th.& Pf. 1953, pl.10, fig.26, p.89,90. Lectotype designated Pflug 1953b.

Comments. This genus has generally been described as triaperturate (Pflug 1953a, p.89; Krutzsch 1961d, p.305; Góczán et al. 1967, p.467). Krutzsch and Góczán et al. consider each aperture to consist of a single endopore with two exposures,one in each surface. It is obvious from their photographs however, and from the material examined from southern England, that the grains are 6-porate with three sub-equatorial pores present on each surface. Where endopores (?atria) are visible there is one associated with each exopore.

Interpollis messelensis Krutzsch 1961d

Plate 17, fig.2-4.

1961 Interpollis messelensis W.Kr., p.306, pl.1, fig.27-28.

1961 Olacaceae Genus B sp. B M.K.S., p.211,212, pl.19, fig.212,213.

1970 Interpollis messelensis W.Kr. 1961; W.Kr.p.327, pl.12, fig.72.

Comparison. This differs from other species of Interpollis in the absence of an equatorial invagination but is comparable in pore and exine structure.

Size. 7 specimens; 19.0 (20.5) 24.5 microns.

Botanical affinity. Probably Olacaceae. This form appears closer to pollen of recent Anacolosa than other species of Interpollis.

Observed distribution. Comparatively rare, present in the Woolwich facies of the Woolwich and Reading Beds, Lignites and Shell Beds, and in the London Clay. A single specimen was recorded in the Thanet Beds at South Lambeth (SL 21). As far as I know this record is the earliest occurrence of this species.

Reported distribution. Lower to Middle Eocene of Europe Góczán et al. 1967; Eocene of the Isle of Wight (M.K.S. 1961).

Interpollis supplingensis (Pf. 1953a) Krutzsch 1961d

Plate 16, fig.26-30.

1953 Intratriporopollenites supplingensis Pf., p.89, pl.10, fig.26-37.

1961 Interpollis microsupplingensis W.Kr., p.305, pl.1, fig.22-23.

1961 Olacaceae Genus B. sp. a M.K.S., p.210, pl.19, fig. 210, 211.

1967 Interpollis supplingensis (Pf. 1953) W.Kr.1961; Góczán et al. p.467,468, pl.8, fig.1-10.

1968 Interpollis supplingensis (Pf.1953) Kr. 1960; Gr.-Cav. p.59, pl.4, fig.26.

1968 Interpollis microsupplingensis Kr. 1960; Gr.-Cav. p.60, pl.4, fig.27,28.

1973 Interpollis supplingensis W. Kr. 1961; Roche, p.55, pl.3, fig.47-49.

1977 Interpollis microsupplingensis W. Kr. 1961d; W. Kr. & Vanh. p.28, pl.13, fig.6-8 only.

Size. 20 specimens; 17.5 (20.5) 26.0 microns.

Comments. The distincition between I. supplingensis and I. microsupplingensis is based only on size; the former is greater than 20 microns, the latter is 20 microns or less (Krutzsch 1961d, p.305). However, this separation does not hold in practice; Góczán et al. (1967) illustrate several specimens of I. supplingensis which are smaller than 20 microns, while Krutzsch and Vanhoorne (1977, p.28) state that specimens of I. microsupplingensis from Epinois range up to 30 microns. Specimens from the south of England range from 17.5-26.0 microns. Since I. supplingensis has priority I have placed all of my specimens in that species.

Botanical affinity. Probably Olacaceae (M.K.S. 1961).

Observed distribution. Rare, present in Thanet Beds at Oldhaven Gap, the South Lambeth Borehole, throughout the Woolwich and Reading Beds, rare to fairly common in the London Clay. More characteristic of the Woolwich facies.

Reported distribution. Maastrichtian to lower middle Eocene of Europe (Góczán et al. 1967); Sparnacian of the Paris Basin (Gr.-Cav. 1968); Upper Montian and Upper Landenian of Belgium (Roche 1969, W. Kr. & Vanh. 1977); Eocene of the Isle of Wight (M.K.S. 1961).

OTHER SPECIES:

Interpollis velum Krutzsch 1961d See plate 16, fig.24.

OTHER TAXA:

Anacolosidites pseudoefflatus Krutzsch 1959b
See plate 17, fig.1 and Krutzsch 1970, pl.8, fig.171.

TURMA: JUGATES (Jugata Erdtman 1943?) Potonié 1960.

SUBTURMA: TETRADITES Cookson 1947

Ericipites spp.

See plate 17, fig.10 and Thomson & Pflug 1953, p.112, pl. 15, fig.67-70 (Tetradopollenites callidus (R.Pot.) Th. & Pf.) and pl.15, fig.75-77 (Tetradopollenites ericius (R. Pot.) Th. & Pf.); Gruas-Cavagnetto 1968, pl.9, fig.9 (Tetradopollenites callidus (R.Pot.) Th. & Pf. 1953).

Riccisporites tuberculatus Lundblad 1954 (reworked)

See plate 17, fig.7 and Morbey & Dunay 1978, pl.4, fig.13.

FRUITS AND SEEDS

Several fruits and seeds were found in the lignite horizon within the Woolwich and Reading Beds at Shorne Wood, particularly in samples JL 866 and JL 867.

I am indebted to Dr. Margaret Collinson for identification of these specimens. Four main types were recovered:

1. Family Typhaceae; probably Typha.

Plate 17, fig.15 whole specimen.

Comments. Gunther & Hills (1972, pl.7, fig.20,22,23 and 25) illustrate specimens of Costatheca tenuis (Dijkstra) Hall which appear to be identical with my material.

2. Family Typhaceae; Typha-like seed with part of the fruit attached.

Plate 17, fig.14 whole specimen.

Plate 17, fig.13 detail of wall layers; inner hexagonal transverse cells of the seed and outer, longitudinal cells of the fruit.

Plate 17, fig.8 whole specimen.

Plate 17, fig.11 detail of operculum. This is similar to that found in recent Typha, see also Collinson 1978, pl.8.1.

3. Carpolithes sp. B. Collinson 1978; monocotyledonous fruit.

Plate 17, fig.5 whole specimen.

Plate 17, fig.9 detail of cell structure.

Plate 17, fig.6 part of another specimen.

4. Unidentified fruit.

Plate 17, fig.12.

4.2 ACID RESISTANT MICROPLANKTON; DINOFLAGELLATE CYSTS, ACRITARCHS AND OTHER ALGAE.

Introduction.

In this brief study of the dinoflagellate cysts and other algae present in the London Basin only the most common species, or particularly distinctive forms, have been identified. As Appendix 2 shows, the number of specimens counted from each horizon was usually very low and only the presence/absence (rather than percentage occurrence) of most species was recorded.

In this section the algal species recognised are listed, including several reworked specimens. Some of the most common species or those characteristic of a particular horizon are illustrated and either a very brief synonymy is given or several published illustrations of specimens which I consider to be identical with my material are cited. These comparisons are based entirely on illustrations, no type material was examined. Species are not described in detail since the majority are already well documented in the literature, however brief comparisons are made in some cases. The observed distribution of selected species in southern Britain and occurrences reported in the literature (Reported distribution) are summarised.

No supra-generic classification is used since, to date, there is no general agreement on which morphological features have most significance for classifying genera. Furthermore, our knowledge of the relationships between living dinoflagellates and fossil dinoflagellate cysts is still very limited. Genera are therefore arranged alphabetically in three main groups; (i) dinoflagellate cysts, p.179, (ii) acritarchs, p.198, (iii) other algae, p.200.

(i) DINOFLAGELLATE CYSTS.

Genus: ACHOMOSPHAERA Evitt 1963

Achomosphaera alcicornu (Eisenack 1954) Davey & Williams 1966a

Plate 18, fig.6,7.

1954 Hystrichosphaeridium alcicornu Eisenack, p.65, pl.10, fig.1-2, text-fig.5.

1966 Achomosphaera alcicornu (Eisenack) D. & W.; p.50, pl.5, fig.3.

1969 Achomosphaera alcicornu; Gocht, p.34, pl.4, fig.1-8,

1976 Achomosphaera alcicornu; S.-L. & Ch. pl.4, fig.6.

Comments: Eaton (1976, p.236) points out that the only difference between this species and Spiniferites pseudofurcatus (Klumpp) Sargeant 1970 is the presence of paraplate boundaries in the latter. Both species have been included in the Spiniferites group in counts.

Observed distribution. Common in the Thanet Sands. Present in the London Clay.

Reported distribution. Eocene to middle Miocene (D. & W. 1966); Palaeocene to middle Oligocene (Gocht 1969); Palaeocene to early Miocene of the North Sea (Ioakim 1979).

Genus: ALISOCYSTA Stover & Evitt 1978

Alisocysta margarita (Harland) Harland 1979
Plate 18, fig.3,4.

1961 Eisenackia crassitabulata Defl. & Cooks; Alberti, p.32, pl.3, fig.19.

1967 Eisenackia circumtabulata Drugg; S.-L. & Ch., pl.1, fig.1,2.

1979 Agerasphaera margarita Harland; p.29-30, pl.1, fig. 1-12, pl.2, fig.1-10.

1979 Alisocysta rugolirata Damassa; p.193-196, pl.3, fig.7-11.

Observed distribution. Present in the Thanet Beds at Pegwell Bay, up to 9% of microplankton at some horizons.

Reported distribution. Danian of California (Damassa 1979); Heersian (=early Landinian) of Belgium (Schumacker-Lambry & Chateauneuf 1976); Thanet Beds of southern England and Thanetian of North Sea (Knox & Harland 1979); late Palaeocene to earliest Eocene of Germany (Alberti 1961).

Genus: APECTODINIUM Costa & Downie 1976 ex
Lentin & Williams 1977.

Comments. Costa & Downie (1976, p.608) designated Wetzeliella homomorpha as the type species of Wetzeliella subgen. Apectodinium. In 1977 Lentin & Williams raised Apectodinium to generic level.

Although the species listed below have been distinguished there is considerable morphological variation within the genus. Costa & Downie (1976, p.594) consider that "discrimination between species is often difficult due to the continuous variation in the critical morphological characters and the abundance of intermediate forms". Only Apectodinium homomorphum and A. parvum have been separated in the counts although the latter probably includes some of the forms transitional to A. quinquelatum. The presence/absence (rather than percentage occurrence) of other species is shown in Appendix 2. In the text-figures showing dinoflagellate cyst distribution (Chapter 5) all species are included in the group "Apectodinium sp.".

Apectodinium homomorphum (Deflandre & Cookson 1955)
Lentin & Williams 1977.

Plate 18, fig.9-11, cf.fig.8.

1955 Wetzeliella homomorpha Defl. & Cooks; p.254, pl.5, fig.7.

1968 Wetzeliella homomorpha Defl. & Cooks; De Coninck, p.20, pl.3, fig.3-6, ?11.

1973 Wetzeliella homomorpha Defl. & Cooks.; Caro, p.363, pl.5, fig.10.

Observed distribution. Abundant in the Woolwich Shell Beds; rare at the base of the Oldhaven Beds (sample OG 27); present in the London Clay at Alum Bay.

Reported distribution. Widely distributed in the late Palaeocene and early Eocene of northwest Europe and the North Sea. Particularly common in the Sparnacian facies, in the Apectodinium hyperacanthum Zone, and at some levels in the Bracklesham Beds Beds at Alum Bay (Costa & Downie 1976, Ioakim 1979). Total range, late Palaeocene to Oligocene;

equivalent to nannoplankton zones NP9-NP23 of Martini,1970 (Costa & Downie 1979).

Apectodinium hyperacanthum (Cookson & Eisenack 1965) Lentin & Williams 1977

Plate 19, fig.1.

1965 Wetzeliella hyperacantha Cookson & Eisenack; p.134-135, pl.16, fig.3-6.

1973 Wetzeliella hyperacantha Cooks. & Eis.; Caro, p.364-365, pl.5, fig.5.

1976 Wetzeliella (Apectodinium) hyperacantha Cooks & Eis.; Costa & Downie, p.609, pl.5, fig.6.

Observed distribution. Rare in the Woolwich Shell Beds.
Reported distribution. Palaeocene (Cooks, & Eis. 1965); middle Palaeocene-early Ilerdian, equivalent to Woolwich & Reading Beds (Caro 1973); late Palaeocene-early Eocene, Woolwich Beds to basal London Clay, Wetzeliella (A.) hyperacantha Zone (Costa & Downie 1976); early Eocene (A. hyperacanthum Zone) in the North Sea (Ioakim 1979); late Palaeocene, equivalent to Martini's (1970) nannoplankton zones NP9 and base NP10 (Costa & Downie 1979).

Apectodinium parvum (Alberti 1961) Lentin & Williams 1977

Plate 19, fig.2,3.

1961 Wetzeliella (Wetzeliella) parva Alberti; p.8-9, pl.1, fig. 14-18.

1969 Wetzeliella parva Alb.; De Coninck, p.20, pl.3, fig.20.

1968 Wetzeliella parva Alb.; Gr.-Cav. p.92, pl.13, fig.8.

Comments. The distinction between A. parvum and A. quinquelatum is not always clear, transitional forms do occur.
Observed distribution. Woolwich and Reading Beds, common to abundant in the Woolwich Shell Beds.
Reported distribution. Late Palaeocene to early Eocene; Woolwich Beds to basal London Clay in Britain, Landenian in Belgium and Palaozan to ?Untereozan 1 in north Germany (Costa & Downie 1976), equivalent to Martini's (1970) nannoplankton zones NP9 and base NP10 (Costa & Downie 1979).

Apectodinium quinquelatum (Williams & Downie 1966b) Costa & Downie 1979.

Plate 19, fig.6.

1948 Hystrichosphaeridium geometricum Pastiels (pars.); p.41, pl.4, fig.4,8.

1966 Wetzeliella (Wetzeliella) homomorpha var. quinquelata W. & Downie; p.191, pl.18, fig.7.

1973 Wetzeliella homomorpha var. quinquelata W. & Downie; Caro, p.364, pl.2, fig.5.

1973 Wetzeliella homomorpha subsp. quinquelata (W. & Downie 1966) Lentin & Williams; p.141.

1979 Apectodinium quinquelatum (Williams & Downie) Lentin & Williams 1977 (sic); Ioakim p.91, pl.19, fig.4.

1979 Wetzeliella (Apectodinium) quinquelata (W. & Downie) Harland p.67, pl.1, fig.11, pl.2, fig.16.

1979 Apectodinium quinquelatum (Williams & Downie) Costa & Downie; p.43.

Observed distribution. Present in the Woolwich Shell Beds. Reported distribution. Occasional in the Sparnacian of the Paris Basin (Gruas-Cavagnetto 1968); middle Palaeocene-middle Ilerdian (equivalent to early Eocene) of Spain (Caro 1973); early Eocene, London Clay, in Britain (Williams & Downie 1966b); early Eocene in Belgium and Germany (Pastiels 1948, Alberti 1961) and in the northern North Sea (Ioakim 1979). Total range, latest Palaeocene to late Eocene, equivalent to Martini's (1970) nannoplankton zones, top NP9 to NP18 (Costa & Downie 1979).

Genus: AREOLIGERA Lejeune-Carpentier 1938

Comments. Species of Areoligera and Glaphrocysta are common at some horizons in the Thanet Beds and the Woolwich and Reading Beds. In counts most specimens have been placed in a broad group which includes species from both of these genera. A few individual species have been recorded as "present" but usually without any quantitative data (see Appendix 2).

Areoligera senonensis Lejeune-Carpentier 1938

Plate 19, fig.4,9,11.

1969 Areoligera senonensis L.-C.; Gocht, p.56, pl.8, fig. 4-6, text-fig. 41.

1975 Areoligera senonensis L.-C.; Williams, pl.1, fig.5.

Observed distribution. Present in the Thanet Beds at Pegwell Bay. No detailed record of its distribution made.
Reported distribution. Late Cretaceous, Senonian (Lejeune-Carpentier 1938); Palaeocene and early Eocene in southern Britain (Davey & Williams 1966 and Downie et al. 1971); Palaeocene and early Eocene in the North Sea (Ioakim 1979).

Areoligera sp.

Plate 19, fig.12,13.

Comments. Specimens are most similar to A. cassicula Drugg 1970, p.811, Fig.2B,3A-B. This species has a series of "annular complexes of intratabular processes" in which the distal ends are connected to form a lace-like pattern. Drugg comments that in some specimens the paratabulation is obscure, the same is true of some of the material from the Thanet Beds. None of my specimens show the broad, flattened distal connections common in Drugg's material.
Observed distribution. Thanet Beds at Pegwell Bay.

Genus: CLEISTOSPHAERIDIUM Davey, Downie, Sarjeant & Williams 1966

"Cleistosphaeridium" group

Plate 19, fig.5,7.

Comments. This is a very broad group of chorate cysts with nontabular processes which are numerous, relatively short, delicate and distally closed. Several archeopyle types occur. In counts the following species have been placed here.

a) Cordosphaeridium microtriaina (Klumpp) Eisenack 1963b see De Coninck 1969, pl.8, fig.28-29, pl.9, fig.1-4;

b) C. uncinispinosum De Coninck 1969, see De Coninck pl.9, fig.6-8;

c) Operculodinium centrocarpum (Defl. & Cooks.) Wall 1967; see Hystrichosphaeridium centrocarpum Defl. & Cooks. 1955, pl.8, fig.3,4; O. centrocarpum in Wall 1967, pl.16, fig.1,2,5 and plate 23, fig.11,12 herein;

d) Lingulodinium machaerophorum (Defl. & Cooks.) Wall 1967, see Hystrichosphaeridium machaerophorum Defl. & Cooks. 1955, pl.9, fig.4,8; L. machaerophorum in Wall 1967, pl.15, fig.16-17;

e) Undifferentiated chorate cysts of this general morphology, see plate 19, fig.5,7 herein.

Observed distribution. The group is relatively common in the Thanet Beds, the Woolwich and Reading Beds (particularly in the centre of the London Basin) and in the London Clay.

Genus: DEFLANDREA Eisenack 1938 emend. Lentin & Williams 1976

Deflandrea dartmooria/oebisfeldensis

Plate 20, fig.2,3,5-7,11.

1959 Deflandrea oebisfeldensis Alberti; p.95-96, pl.8, fig.10-13.

1969 Deflandrea oebisfeldensis Alb.; De Coninck p.17, pl. 2, fig.3-4, 8-10.

1969 Deflandrea oebisfeldensis an phosphoritica; De Coninck, pl.2, fig.13-14.

1974 Deflandrea oebisfeldensis Alb.; Gr.-Cav. pl.1, fig.13.

1976 Deflandrea speciosa; S.-L. & Ch. pl.5, fig.3-4.

1979 Deflandrea oebisfeldensis Alb.; Knox & Harland pl.2, fig.1-9.

1979 Deflandrea oebisfeldensis Alb.; Ioakim pl.8, fig.7.

1979 Deflandrea dartmooria Cooks. & Eis. 1965; Ioakim pl. 8, fig.3.

Comments. This form is characterised by the presence of weak paratabulation on the periphragm, indicated by an ornament of low cones typically arranged in intratabular clusters or in rows (plate 20, fig.3,6) and by the archeopyle.

From the literature it is obvious that the distinction between the three species D. dartmooria, D. oebisfeldensis and D. speciosa is not clear. De Coninck (1969 p.17) describes his specimens as D. phosphoritica to D. oebisfeldensis;

they have an ornament comparable to that seen in the London Basin material (see his pl.2, fig.13-14). De Coninck comments on the variation in the shape of his specimens, they range from elongated forms close to D. dartmooria and D. oebisfeldensis to larger but shorter specimens like D. phosphoritica subsp. australis Cooks. & Eis. 1961. Similar variations occur in specimens I have included in D. dartmooria/oebisfeldensis from the London Basin. Few authors have recognised D. dartmooria Cooks. & Eis. 1965. The apical and antapical horns are perhaps more elongated than in D. oebisfeldensis and the paratabulation is better defined. I consider most of the specimens I have recorded to be transitional between D. dartmooria and D. oebisfeldensis.

Observed distribution. Characteristic of the Thanet Beds although never abundant.

Reported distribution. D. oebisfeldensis, Thanetian to Ypresian (varielongituda Zone of Costa & Downie 1976). Knox & Harland (1979) consider D. dartmooria ss. to be restricted to the Thanetian.

Deflandrea sp. A.

Plate 20, fig.8-10.

Comments. Specimens are most similar to De Coninck's illustrations of Deflandrea aff. tenera Krutzsch (De Coninck 1969, p.17, pl.1, fig.20-22). Other superficially similar forms include Deflandrea wetzeli Morgenroth 1966 and some specimens referred to Deflandrea denticulata Alberti 1959 forma minor De Coninck 1969 (e.g. De Coninck pl.1, fig. 16-17), although the later has larger apical and antapical horns.

Observed distribution. Common at some levels in the Woolwich Beds (see Appendix 2).

Reported distribution. Ypresian of Belgium (De Coninck 1969). Geiselodinium tenerum (Krutzsch) Stover & Evitt 1978 was originally described from freshwater levels within leaf-bearing, coally horizons in the brown coals of Geiseltal (Krutzsch 1962).

OTHER SPECIES:

Deflandrea heterophlycta Deflandre & Cookson 1955
See plate 20, fig.12 and Defl. & Cooks. 1955, p.249-250, pl.5, fig.6, text-fig.5; Ioakim 1979, p.43, pl.7, fig.1,3.

Deflandrea phosphoritica Eisenack 1938
See plate 20, fig.13 and Eis. 1938, p.187, text-fig. 6; Defl. & Cooks. 1955, p.249, pl.4, fig.5; Morgenroth 1966, p.8, pl.1, fig.3; Williams & Downie 1966c, p.231, pl.26, fig.9; Gocht 1969, p.9, pl.6, fig.5; Eaton 1976, p.290, pl.17, fig.1.

Genus: DRACODINIUM Gocht 1955
Dracodinium solidum Gocht 1955
Plate 21, fig.1.

1966b. Wetzeliella (Wetzeliella) solida (Gocht) Williams & Downie, pl.20, fig.7.
1979 Dracodinium solidum (Gocht) Costa & Downie sous presse; Ioakim, pl.19, fig.11.

Comments. Williams & Downie (1966b, p.195) transferred Dracodinium solidum to Wetzeliella subsp. Wetzeliella thus removing the type of the genus and making Dracodinium superfluous (Lentin & Williams 1977, p.55). However, subsequent reorganisation of the genus Wetzeliella s.l. has taken place (see Vozzhenikova 1967, Costa & Downie 1976, Lentin & Williams 1977, Harland 1979 and Costa and Downie 1979) and Dracodinium has been reinstated as a valid genus (Costa & Downie 1979, p.43).
Observed distribution. Rare in the London Clay at Alum Bay (AB 52 and AB 54).
Reported distribution. Early-?late Eocene of Germany (Gocht 1969); rare in the London Clay of the London Basin and the Isle of Wight (Williams & Downie 1966b); early Eocene in Belgium, early to late Eocene in England and Germany (Costa & Downie 1976); early-middle Eocene in the North Sea (Ioakim 1979); total range from early-late Eocene, equivaland to Martini's (1970) nannoplankton zones NP 11-NP14,

?NP14-?NP19 (Costa & Downie 1979).

Genus: GLAPHROCYSTA Stover & Evitt 1978.

Comments. As stated above, specimens of Glaphrocysta and Areoligera have been included in a single group for counts. There is considerable morphological variation within both genera and individual species are not always easily differentiated.

Glaphrocysta ordinata (Williams & Downie 1966c) Stover & Evitt 1978

Plate 21, fig.8,9,11-13,15, plate 22, fig.1,3.

1966 Cyclonephelium ordinatum W. & D., p.225-226, pl.25, fig.3.

1969 Cyclonephelium ordinatum W. & D.; Gocht, p.58-60, pl.8, fig.1-3, text-fig.42.

1979 Areoligera senonensis L.-C.; Ioakim, pl.2, fig.11.

Observed distribution. Common at some levels of the Thanet Beds at Pegwell Bay. Present in the Woolwich & Reading Beds (Shell Beds and Striped Loams).

Reported distribution. Early Ilerdian of Spain, equivalent to late Palaeocene-early Eocene (Caro 1973); late Palaeocene-early Eocene (Thanet Beds to London Clay) of southern England (Hussain 1967); early Eocene of north Germany (Gocht 1969); early Eocene of southern England (Williams & Downie 1966c) and North Sea (Ioakim 1979); early-middle Eocene in the Hampshire Basin (Bujak et al. 1980).

Glaphrocysta pastielsi (Deflandre & Cookson 1955) Stover & Evitt 1978

Plate 21, fig.2-6.

1948 Membranilarnax cf. liradiscoides Wetzel; Pastiels pl.5, fig.15.

1969 Cyclonephelium pastielsi Defl. & Cooks.; Gocht, p.60, pl.8, fig.15.

Comments. The species is characterised by narrow trabeculae which link processes distally. There are no areas with

reticulate distal "platforms" as occur in G. exuberans.

Observed distribution. Woolwich Beds and London Clay. Most specimens belonging to this species have been recorded as Glaphrocysta sp. in counts consequently no information is available on the detailed distribution of the species in the London Basin.

Reported distribution. Eaton (1976, p.259) suggests that several records of this species are mis-identifications. He considers the only reliable records to be those from the lower Eocene of Belgium (Pastiels 1948, De Coninck 1965, 1968) and from northern France (Gruas-Cavagnetto 1968). Gocht (1969) records it from the Untereozän 1 of north Germany.

Glaphrocysta cf. retiintexta (Cookson 1965a) Stover & Evitt 1978

Plate 22, fig.5.

cf.1965 Cyclonephelium retiintextum Cooks. p.88, pl.11, fig.4.

Observed distribution. Illustrated specimen from the Thanet Beds at Pegwell Bay, detailed distribution not recorded.

Reported distribution. Late Cretaceous, Victoria, Australia (Cooks. 1965a).

OTHER SPECIES:

Glaphrocysta aff. exuberans (Defl. & Cooks. 1955 ex Eaton 1976) comb. nov.

See Cyclonephelium aff. exuberans Defl. & Cooks. ex Eaton 1976, p.256-267, pl.7, fig.7; Cyclonephelium pastielsi Defl. & Cooks. in W. & Downie 1966c, pl.25, fig.2 .

Observed distribution. Thanet Beds at Pegwell Bay.

Genus: HAFNIASPHAERA Hansen 1977

Hafniasphaera sl.

Plate 21, fig.14.

Comments. The genus comprises chorate cysts with a subspherical or ovoid central body, composed of two layers,

(endophragm and periphragm) either or both of which may contain numerous, evenly distributed vesicles (vacuoles) (Hansen 1977, p.13). The vesicles may be spherical or, when interconnected, form a fine reticulum within the cyst wall. Processes are intertabular, formed by the periphragm and are solid or hollow, with or without vesicles. The archeopyle is precingular. Paratabulation is indicated by the presence of sutural crests, weak bulges in the periphragm, by the alignment of vesicles, or by the arrangement of processes only (see Hansen p.13 for details).

I consider the illustrated specimen (plate 21, fig.14) to be comparable to Hystrichosphaeridium sp. C (in Gruas-Cavagnetto 1968, pl.18, fig.14,16); Baltisphaeridium cf. tripodes Morz-Kerf. 1966 (in Chateauneuf & Gruas-Cavagnetto 1968, pl.6, fig.5,6); Hystrichosphaera sp. (in De Coninck 1969, pl.7, fig.30,31) and Achomosphaera sagena (in Ioakim 1979, pl.1, fig.6).

In counts several additional species have been included in Hafniasphaera sl., particularly Achomosphaera sagena Davey & Williams 1966a, Hafniasphaera septata (Cookson & Eisenack 1967) Hansen 1977 and Spiniferites crassipellis (Deflandre & Cookson 1955) Sarjeant 1970.

Observed distribution. See Appendix 2.

Reported distribution. Spiniferites crassipellis is a long-ranging species, recorded from the late Cretaceous to the Miocene (Clarke & Verdier 1967). Achomosphaera sagena is reported from the Cretaceous (Cenomanian to Senonian, Davey & Williams 1966a, Clarke & Verdier 1967), Danian-Thanetian of the North Sea (Ioakim 1979) and the Eocene of southern England (Bujak et al. 1980). Hafniasphaera septata occurs from the Danian to the early Eocene (as Spiniferites septatus Drugg & Stover 1975). The genus Hafniasphaera is particularly characteristic of the Danian (Hansen 1977).

Genus: HYSTRICHOKOLPOMA Klumpp 1953

Hystrichokolpoma mentitum McLean 1974

Plate 22, fig.2,4.

1974 Hystrichokolpoma mentitum McLean, p.66, pl.8, fig. 1-5.

Comments. Harland (1979, p.33) mentions the general similarity between H. mentitum and Alisocysta margarita. He suggests that the former might be an extreme variant in the morphological range of A. margarita, having exceptionally high penetabular membranes.

Observed distribution. Thanet Beds at Pegwell Bay, rare.

Reported distribution. Mclean records it as extremely rare (only three specimens, less than 1% of the total microplankton) in the late Palaeocene, Aquia Formation of Maryland and Virginia U.S.A.

Genus: HYSTRICHOSPHAERIDIUM Deflandre 1937b emend. Davey & Williams 1966b.

Hystrichosphaeridium sp. cf. H. patulum Davey & Williams 1966b.

Plate 22, fig.6,9,11.

cf.1966 Hystrichosphaeridium patulum Davey & W.; p.60, pl.10, fig.5.

1969 cf. Hystrichosphaeridium patulum Davey & W.; De Coninck, p.35, pl.10, fig.7,8.

1977 Adnatosphaeridium ? willieriae De Coninck 1976; De Coninck, p.40, pl.1, fig.5,6.

Comments. My specimens are most similar to those illustrated by De Coninck (1977). H.patulum and A.? willieriae appear to be very similar in general morphology; they both have two types of processes,(one broad and tubular, the other very narrow),which are both expanded distally. De Coninck describes thread-like extensions which link the distal ends of the processes in A.? willieriae. This feature is not visible in my specimens from the London Basin although the everted tops of the broad, flimsy tubular processes lying behind the very thin processes sometimes give the appearance of trabeculae. The broad processes are often linked proximally (plate 22, fig.9). I have been unable to determine the number of processes on my specimens, at some levels of focus the narrow processes look almost as if they might be thickenings along the broader processes. The holotype of H. patulum has fewer processes than A.? willieriae and specimens from the London

Basin but is otherwise similar.

Observed distribution. Thanet Beds.

Reported distribution. London Clay, Isle of Wight (Davey & Williams 1966b); Ypresian in the Kallo Borehole, Belgium (De Coninck 1969); H. stephanophorum occurs in the middle and late Oligocene of the lower Rhine, Germany (Benedek 1972).

Hystrichosphaeridium tubiferum (Ehrenburgh 1838) Deflandre 1937b emend. Davey & Williams 1966b.

Plate 22, fig.7,10,12.

1966 Hystrichosphaeridium tubiferum (Ehr.) Defl.; Davey & W., p.56-57, pl.10, fig.2.

1968 Hystrichokolpoma bulbosa (Ehr.) emend. Morg. pl.45, fig.4-5 only.

1976 Hystrichosphaerdium tubiferum (Ehr.) Defl.; Eaton, p.272, pl.11, fig.4.

Observed distribution. Common in the Thanet Beds.

Reported distribution. Cretaceous (Albian and younger, Davey & Verdier 1971) to lower Eocene (Davey & W. 1966b). Danian (Morgenroth 1968). Eaton (1976, p.272) suggests that specimens reported from sediments younger than early Eocene are most probably species of Homotryblium Davey and Williams 1966.

Genus: INVERSIDINIUM McLean 1973b

Inversidinium exilimurum McLean 1973b

Plate 24, fig.1.

1973b Inversidinium exilimurum McLean, p.730-732, pl.90, fig.1-9.

1976 Inversidinium exilimurum McLean 1973; Schumacker-Lambry & Chateauneuf pl.7, fig.9.

Observed distribution. Rare in the Thanet Beds at Pegwell Bay and Oldhaven Gap.

Reported distribution. Maastrichtian to early Eocene of offshore Labrador (Ioakim 1979); late Palaeocene (McLean 1973b, S.-L. & Ch. 1976).

Genus: MICRODINIUM Cookson & Eisenack 1960a

?Microdinium sp. 2 Schumacker-Lambry & Chateauneuf 1976.

Plate 23, fig.2-4.

1976 ?Microdinium sp. 2 S.-L. & Ch., p.270, pl.1, fig.7,8.
cf. 1974 Membranosphaera sp. Harris, pl.4, fig.5,6.

Comments. The specimens from the London Basin compare well with that illustrated by Schumacker-Lambry & Chateauneuf. A paracingulum and parasulcus are distinguishable although they are poorly defined. The ornament of short, straight processes appears to be non-tabular. Some processes are linked proximally (plate 23, fig.2,4) and all appear to be linked distally by delicate trabeculae.

Membranosphaera sp. of Harris (1974) from the Palaeocene of the Ninetyeast Ridge in the Indian Ocean, is very similar and may be equivalent.

Poorly orientated specimens, which may belong to this species have been placed in a separate group, aff. ?Microdinium sp.2.

Observed distribution. Common at some levels in the Thanet Beds at Pegwell Bay.

Reported distribution. Present in the Heersian (base of the Landenian) Belgium (S.-L. & Ch. 1976); Palaeocene, Indian Ocean (Harris, 1974).

Genus: PHTHANOPERIDINIUM Drugg & Loeblich 1967.

Phthanoperidinium crenulatum (De Coninck 1975) De Coninck 1977

Plate 23, fig.16-18.

1975 Peridinium crenulatum De Coninck, p.96, pl.17, fig.5-7, 12-13, 14-15.

1977 Phthanoperidinium crenulatum (De Coninck 1975) De Coninck, pl.6, fig.27,28,29.

Description. Cysts rhomboidal in outline, ± small apical horn. Paratabulation (not determined) indicated by denticulate parasutural crests; archeopyle intercalary, type 3I.

Size. (2 specimens measured) Length 48-52 microns; width 44-48 microns.

Observed distribution. Present in the Thanet Beds (Palaeocene) at Oldhaven Gap and Pegwell Bay.

Reported distribution. Ypresian in Belgium (De Coninck 1975, 1977).

Genus: SENTUSIDINIUM Sarjeant & Stover 1978

Sentusidinium sp.

Plate 22, fig.14, plate 23, fig.1.

Comments. Some of the specimens recorded from the London Basin may be reworked, others, from their preservation, appear to be in situ.

Observed distribution. Rare in the Thanet Beds; present in the Reading Beds at the western end of the London Basin; rare in the Woolwich and Reading Beds in the centre of the London Basin; common at some levels of the London Clay at Alum Bay (probably reworked).

Genus: TRICHODINIUM Eisenack & Cookson 1960

?Trichodinium sp.

Plate 23, fig.8,13,14.

Comments. The specimens included here are equivalent to "Trichodinium spinatum" Denison (unpublished thesis 1977, p.15, pl.1, fig.5). Vectidinium stoveri Liengjarern et al. 1980 is superficially similar (see 1980, pl.490, pl.54, fig.7).

The cysts are generally spheroidal in outline but frequently show secondary folds. The surface has a dense cover of granules and short spines (up to c.3 microns long) which are broad at the base and narrow to hair-like projections distally. The apical tuft or horn which Denison describes has not been seen in the present material. A weakly defined paracingulum is the only indication of paratabulation. The archeopyle is not discernible but in several specimens the cyst splits along the paracingulum and rare hemispheres (epicyst or hypocyst) occur. Further study is necessary to determine whether this splitting

is related to archeopyle formation but if this proved to be the case the species would need to be transferred to a more appropriate genus. In counts this species is combined with Tubidermodinium sp. in ?Trichodinium sp.

Observed distribution. Common in the Woolwich Shell Beds, occasional specimens in the London Clay.

Reported distribution. "Trichodinium spinatum" occurs in the Woolwich and Reading Beds, Shell Beds, at Charlton, Upnor, Bean, Erith and Newhaven (Denison 1977). V. stoveri is thought to be a non-marine dinoflagellate cyst, possibly a good indicator of oligohaline conditions. It is recorded from the upper Headon and Lower Hamstead Beds (late Eocene-Oligocene) of the Isle of Wight (Liengjarern et al. 1980).

Genus: TUBIDERMODINIUM Morgenroth 1966

Tubidermodinium sp.

Plate 23, fig.15.

Comments. These specimens are identical to "Tubidermodinium granulatum" Denison (unpublished thesis 1977, p.25, pl.1, fig.12).

The cysts are sub-spherical to spherical with well defined, smooth pandasutural zones and an intratabular ornament of granules c.2-3 microns high. Denison describes the archeopyle as epitractal but the few specimens recorded here are folded and too poorly orientated to confirm this.

In counts Tubidermodinium sp. is combined with ?Trichodinium sp. since, in poorly preserved and folded specimens the two species are not easily separable.

Observed distribution. Rare in the Woolwich and Reading Beds Shell Bed.

Reported distribution. Woolwich and Reading Beds Shell Bed at Charlton, Upnor, Erith, Bean, Newhaven and its equivalent at Cap d'Ailly, France (Denison 1977).

OTHER SPECIES RECORDED:

Achomosphaera ramulifera (Deflandre) Evitt 1963.

A. sagena Davey & Williams 1966a.

Adnatosphaeridium aemulum (Deflandre) Williams & Downie 1969 (reworked)

A. caulleryi (Deflandre) Williams & Downie 1969 (reworked).

A. reticulense (Pastiels) De Coninck 1969.

A. robustum (Morgenroth) De Coninck 1975.

?A. patulum Williams & Downie 1966.

See plate 18, fig.5 and W. & D. 1966, p.217, pl.25, fig.1,2; Caro 1973, p.343, pl.3, fig.1; Thalassiphora pelagica (Eis.) Eisenack & Gocht in Gocht 1969, pl.5, fig.8 only.

Apteodinium granulatum Eisenack 1958 (reworked).

Athigmatocysta glabra Duxbury 1977 (reworked).

Cordosphaeridium fibrospinosum Davey & Williams 1966b.

See plate 19, fig.10 and D. & W. 1966b, p.86, pl.5, fig.5; Gocht 1969, p.43, pl.2, fig.3-4; Eaton 1976, p.253, pl.6, fig.6; Ioakim 1979, p.30, pl.4, fig.7. cf. C. fibrospinosum plate 18, fig.1 herein.

Cordosphaeridium gracile (Eisenack 1954) Davey & Williams 1966b.

See D. & W. 1966b, p.84, pl.3, fig.8; Cordosphaeridium inodes gracilis (Eis.) Gocht 1969, pl.1, fig.1-8.

Cordosphaeridium inodes (Klumpp) Eisenack 1963b

See plate 20, fig.4 and Hystrichosphaeridium inodes Klumpp in Defl. & Cooks. 1955, pl.8, fig.7; Cordosphaeridium inodes subsp. inodes (Klumpp) Gocht 1969, pl.1, fig.11-12; C. inodes De Coninck 1969, pl.8, fig.15.

Cordosphaeridium spp.

See plate 19, fig.8 and plate 20, fig.1.

Ctenidodinium elegantulum Millioud 1969 (reworked)

Cribroperidinium edwardsii Deflandre & Cookson 1955 (reworked).

Cyclonephelium distinctum Deflandre & Cookson 1955 (reworked).

Dingodinium albertii Sarjeant 1966c (reworked).

Diphyes colligerum (Deflandre & Cookson 1955) Cookson 1965a

See plate 21, fig.7,10 and Hystrichospheridium colligerum Defl. & Cooks. 1955, p.278, pl.7, fig.3; Diphyes colligerum Cooks. 1965a, p.86-87; Davey & W. 1966b, p.96-97, pl.4, fig.2-3; Gruas-Cavagnetto 1968, pl.12, fig.19; De Coninck 1969, p.33, pl.9, fig.13-18.

Gardodinium trabeculosum (Gocht). Alberti 1961 (reworked).

Glaphrocysta divaricata (W. & D.) Stover & Evitt 1978.

Gonyaulacysta ambigua (Deflandre) Sarjeant 1969 (reworked).

G. dangeardii Sarjeant 1968 (reworked).

G. jurassica (Deflandre) Norris & Sarjeant 1965 (reworked).
See plate 23, fig.5 and Sarjeant 1975, pl.2, fig.6.

G. longicornis (Downie) Sarjeant 1969 (reworked).

Hafniasphaera septata (Cookson & Eisenack) Hansen 1977.

Homotryblium pallidum Davey & Williams 1966b.
See plate 22, fig.8,13 and D. & W. 1966b, p.102, pl.12, fig.4,6.

Homotryblium sp. See plate 22, fig.15.

Hystrichodinium voigtii (Alberti) Davey 1974 (reworked).

Kisselovia tenuivirgula (Williams & Downie) Lentin & Williams 1976.

Leptodinium mirabile Klement 1960 (reworked).

Microdinium sp.; plate 23, fig.10.

aff. ?Microdinium sp. 2 Schumacker-Lambry & Chateauneuf 1976.

Nannoceratopsis gracilis Alberti 1961 emend. Evitt 1962 (reworked).
See plate 23, fig.7 and Alberti 1961, p.30, pl.7, fig.6; Nannoceratopsis deflandrei Evitt 1961b, p.308, pl.1, fig.1-14; N. senex van Helden in Davey & Riley 1978, pl.3, fig.5.

Nannoceratopsis pellucida Deflandre 1938 emend. Evitt 1961b (reworked).

Oligosphaeridium complex (White) Davey & Williams 1966b.

Palaeostomocystis laevigata Drugg 1967.
See plate 23, fig.6 and Drugg 1967, p.35, pl.6, fig.14,15; Drugg & Stover 1975, pl.5, fig.12; Williams & Lentin 1975, pl.2, fig.12; Schumacker-Lambry & Chateauneuf 1976, pl.7, fig.12,13.
Observed distribution. Common in the Thanet Beds.
Reported distribution. Maastrichtian and Danian (Drugg 1976; Campanian to early Palaeocene (Drugg & Stover 1975, Williams & Lentin 1975); Palaeocene, lowest part of the Landenian (?reworked) (S.-L. & Ch. 1976).

Pareodinia ceratophora Deflandre 1947c emend. Gocht 1970b (reworked).

Polysphaeridium subtile Davey & Williams 1966b.

Prolixosphaeridium sp.

Spiniferites cingulatus (Wetzel) Sarjeant 1970.

S. cornutus (Gerlach) Sarjeant 1970.

S. crassipellis (Deflandre & Cookson) Sarjeant 1970.

S. pseudofurcatus (Klumpp) Sarjeant 1970.

S. ramosus (Ehrenberg) Loeblich & Loeblich 1966.

Stephanelytron redcliffense Sarjeant 1961a.

See plate 23, fig.9 and Sarjeant 1961a, p.110, pl.15, fig.11; Davey & Riley 1978, pl.3, fig.2.

Comments. Reworked. A single specimen recorded from the Striped Loams in the Woolwich and Reading Beds at Charlton (CH18). Reported range of the genus is late Callovian to early Kimmeridgian (Davey & Riley 1978).

Thalassiphora spp. (not illustrated). ?Thalassiphora sp.,

See plate 18, fig.2.

Wanaea sp. (reworked).

Wetzeliella lunaris Gocht 1969.

See plate 23, fig.19 and Gocht 1969, p.13, pl.10, fig.1-3; Eaton 1976, p.302, pl.19, fig.2.

Observed distribution. The illustrated specimen is from the London Clay at Leaden Roding (LR14), otherwise included in Wetzeliella spp. in counts.

Reported distribution. Lower and middle Eocene (Eaton 1976); early Eocene, equivalent to Martini's (1970) nannoplankton zones NP11-NP13 (Costa & Downie 1979).

(ii) ACRITARCHS

Genus: BALTISPHAERIDIUM Eisenack 1958.

Baltisphaeridium sp. B. Gruas-Cavagnetto 1968.

Plate 24, fig.2,3.

1968 Baltisphaeridium sp. B. Gr.-Cav. p.97, pl.18, fig.1-2.

1968 Baltisphaeridium fsp. (PL26) Chateauneuf & Gruas-Cavagnetto, pl.7, fig.5.

1970 Baltisphaeridium PL26; Gr.-Cav., pl.2, fig.25.

Comments. The specimens from the London Basin compare well with those listed above. Their processes are similar to those of the paratype of Baltisphaeridium funginum Morgenroth (1966, pl.3, fig.8) but they are considerably longer (10-15 microns rather than 3-4 microns as in B. funginum) and

are different from the very short, mushroom shaped processes of the holotype (Morgenroth 1966, pl.3, fig.7).

Observed distribution. Present in the Woolwich and Reading Beds, the Shell Beds, in the central part of the London Basin (Charlton and Swanscombe) and in the Reading Beds at Pincents Kiln. Rare in the London Clay.

Reported distribution. Rare in the Sparnacian in the Paris Basin (Gr.-Cav. 1968); Sparnacian (Argile et lignites) in the Le Tillet and Mountjavout boreholes, Paris Basin (Ch. & Gr.-Cav. 1968); present in the Woolwich Beds at Swanscombe (Gr.-Cav. 1970).

Genus: HOROLOGINELLA Cookson & Eisenack 1962a

Horologinella apiculata Cooks. & Eis. 1962a
Plate 24, fig.11.

1962a Horologinella apiculata Cooks. & Eis. p.272, pl.37, fig.4.

Horologinella incurvata Cooks. & Eis. 1962a.

1962a Horologinella incurvata Cooks. & Eis., p.272, pl.37, fig.5.

1969 Horologinella incurvata Cooks. & Eis.; De Coninck, p.44, pl.13, fig.16-18.

Comments. Stover & Evitt (1978, p.54) consider only the type species of Horologinella, H. lineata, to be a dinoflagellate cyst, all other species are regarded as acritarchs. They are preparing a paper to transfer these to a new acritarch genus.

In counts H. apiculata and H. incurvata have been recorded as Horologinella spp.

Observed distribution. Horologinella spp. are never common but occur in the Thanet Beds from most localities in the London Basin and are very characteristic of the Thanet Beds microplankton association.

Reported distribution. Cookson and Eisenack (1962a) report H. apiculata from the Campanian and H. incurvata from probable lower Eocene sediments from Western Australia. De Coninck (1969) reports H. incurvata from only one horizon in the Ypresian of the Kallo borehole, Belgium.

OTHER SPECIES RECORED:

Comasphaeridium cometes (Valensi) De Coninck 1969

See plate 24, fig.4 and De Coninck 1969, p.58, pl.16, fig.34-41.

Cymatiosphaera eupeplos (Valensi) Deflandre 1954

See De Coninck 1969, p.55, pl.16, fig.14-17.

Cymatiosphaera punctifera Deflandre & Cookson 1955

See plate 24, fig.8,12 and Defl. & Cooks. 1955, p.289, pl.7, fig.14.

Cymatiosphaera tortuosa De Coninck 1969

See De Coninck 1969, p.55, pl.16, fig.18-19.

Leiospheres (undifferentiated).

Trigonopyxidia ginella (Cooks. & Eis.) Downie, & Sarjeant 1965

See plate 24, fig.7 and Cooks. & Eis. 1960a, p.11, pl. 3, fig.18-20; Schumacker-Lambry & Chateauneuf 1976, pl.7, fig.10.

Comments. Considered to be an acritarch by Schumacker-Lambry 1978, p. 52.

Observed distribution. Rare in the Thanet Beds, possibly reworked.

Reported distribution. Cretaceous, late Albian to Maastrichtian (Williams & Lentin 1975); Palaeocene, early Landenian (Sch.-L. & Ch. 1976).

Micrhystridium spp.

Veryhachium spp.

(iiia) OTHER ALGAE: CHLOROPHYTA.

Genus: PARALECANIELLA Cookson & Eisenack 1970

Paralecaniella indentata (Deflandre & Cookson) Cookson & Eisenack 1970

Plate 24, fig.6.

1955 Epicephalopyxis indentata Defl. & Cooks. p.292, p.9, fig.5-7.

1968 Epicephalopyxis indentata Defl. & Cooks. 1955; Gr.-Cav. p.99, pl.15, fig.10-13.

Observed distribution. Irregular occurrence from Thanet Beds to London Clay. At some horizons in the Oldhaven Beds at

Oldhaven Gap it forms 90% or more of the total microplankton (OG 19, OG 22).

Reported distribution. Palaeocene to Miocene (Defl. & Cooks 1955, Cooks. & Eis. 1970).

Genus: PEDIASTRUM Meyen 1829

Pediastrum sp.

Plate 24, fig.15.

1969 Pediastrum spp.; Evitt (in Tschudy & Scott), pl.18-1, fig.13.

Observed distribution. Common to abundant at some horizons of the Woolwich Shell Beds, otherwise occasionally present in that formation and in the London Clay.

Reported distribution. Although living Pediastrum, a colonial green alga, is exclusively a freshwater organism fossil species have been recorded in marine sediments associated with marine microplankton (Evitt 1963, Stanley 1965). These authors suggest that the fossils have been transported from freshwater lakes or streams into a marine environment of deposition.

The genus is widely distributed in Cretaceous to Recent sediments including the early Cretaceous of Pakistan (Evitt 1963); the Cretaceous of North America (Tschudy 1969) and North Africa (personal observation); the Eocene Green River Shales of Utah, U.S.A. (Stanley 1965); the early-late Eocene of off-shore Labrador and the North Sea (Ioakim 1979); the Neogene of Sumatra (Wilson & Hoffmeister 1953); the Tertiary of Venezuela (Tschudy 1969) and the Cenozoic of Australia (Cookson 1953).

(iiib) OTHER ALGAE: ZYGNEMATACEAE - TYPES.

Genus: OVOIDITES Potonié ex Thomson & Pflug 1953

Comments. The distinction between this genus and Schizosporis Cookson & Dettmann 1959 is not clear. Stanley (1965, p.267) suggests that the latter is more spherical to spheroidal in shape while Ovoidites is distinctly fusiform. He considers that the detailed subdivision of Ovoidites by Krutzsch

(1959) is unjustified and that some of Krutzsch's species should be assigned to Schizosporis. The fact that Van Geel and Van der Hammen (1978) recognise spores of the genus Spirogyra (Zygnemataceae) which are morphologically similar to specimens which have been included in both Ovoidites (e.g. Spirogyra sp. (Type 3a), pl.4, fig.45) and in Schizosporis (Spirogyra sp. (Type 1), pl.3, fig.34-41) further suggests that the separation into two genera is probably not justifiable. Van Geel and Van der Hammen (1978) consider the reticulate forms to be comparable to Ovoidites and the smooth forms to Schizosporis. It is important to note however, that the type species of Schizosporis is reticulate (see Cookson & Dettmann 1959).

Ovoidites ligneolus (Potonié) Thomson & Pflug 1953
Plate 24, fig.5.

1953 Ovoidites ligneolus (Potonié) Th. & Pf. p.113, pl.15, fig.100.

1965 Ovoidites ligneolus Potonié ex Th. & Pf; Stanley p.316, pl.32, fig.12-13.

1966 Ovoidites fsp. 6, Sontag, pl.79, fig.1a-d.

1968 Ovoidites microligneolus W. Kr. 1959; Gr.-Cav. p.80, pl.9, fig.4-5.

Observed distribution. The genus is present in the lignite within the Woolwich and Reading Beds at Shorne Wood and Swanscombe.

Reported distribution. Sparnacian in the Paris Basin (Gr.-Cav. 1968); middle Eocene in Germany (Th. & Pf. 1953); Miocene in Germany (Sontag 1966).

Genus: SCHIZOSPORIS Cookson & Dettmann 1959
Schizosporis parvus Cooks. & Dett. 1959.
Plate 24, fig.18, 19.

1959 Schizosporis parvus Cooks. & Dett. p.216, pl.1, fig.15-20.

1965 Schizosporis laevigatus Stanley p.268, pl.23, fig.6-7, pl.37, fig.4-5.

1968 Ovoidites boureaui Gruas-Cavagnetto pl.11, fig.1-2.
1977 Ovoidites sp. Gr.-Cav. pl.21, fig.8.
1977 Ovoidites sp. 1 Gr.-Cav. pl.21, fig.5.
1977 Ovoidites sp. 3 Gr.-Cav. pl.21, fig.10.
1977 Ovoidites elongatus (Hunger 1952) W. Kr.; Gr.-Cav. pl.21, fig.9.
1978 Spirogyra species (Type 1) Van Geel & Van der Hammen pl.3, fig.34-41, pl.4, fig.42.

Observed distribution. See below.

Schizosporis spriggi Cookson & Dettmann 1959

Plate 24, fig.9.

1959 Schizosporis spriggi Cooks. & Dett. p.216, pl.1, fig.10-14.
1968 Ovoidites globus Gruas-Cavagnetto p.80, pl.11, fig. 6,7,11.
1968 Ovoidites globus Nakoman pl.7, fig.7.
1968 Schizosporis texus Elsik p.284, pl.4, fig.11 only.

Comments. Cookson & Dettmann's specimens have a slightly thinner wall than O. globus of Gruas-Cavagnetto and of Nakoman, they are otherwise identical.
Observed distribution. The genus is present in the lignite within the Woolwich and Reading Beds at Shorne Wood and Swanscombe.
Reported distribution. Cretaceous and Tertiary of Australia (Cooks. & Dett. 1959); early Tertiary of northwest Europe (Gr.-Cav. 1968, 1977); early Tertiary of North America (Stanley 1965, Elsik 1968); Miocene of Turkey (Nakoman 1968).

Genus: TETRAPORINA Naumova 1939 ex Bolkhovitina 1953

Tetraporina pellucida Naum. ex Bolk. 1953.

Plate 24, fig.13.

1966 Tetrapidites Klaus 1950; Sontag pl.88, fig.5a-c only.
1977 Tetrapidites laevigatus W. Kr. & Vanhoorne p.4, pl.1, fig.14/15.

1978 Mougeotia spec. (Type 3) zygospores, Van Geel & Van der Hammen p.383, pl.1, fig.13-15.

1978 Mougeotia spec. (Type 2) Van G. & Van der H. p.383, pl.2, fig.18.

1978 Mougeotia sp. Van G. & Van der H. pl.2, fig.17.

Comments. This form was originally described as "angiospermous pollen with four pores" (Naumova 1939, quoted in Jansonius & Hills 1976, card no. 2877) although Scott, Barghoorn & Leopold (1960) note a striking similarity to the modern unicellular green alga Tetraëdon. Krutzsch (1962) suggests it is related to freshwater microplankton. More recently Van Geel & Van der Hammen (1978) have illustrated zygospores of Mougeotia (Zygnemataceae) which are very similar to Tetraporina pellucida.

Observed distribution. Present in the lignite within the Woolwich and Reading Beds at Shorne Wood and Swanscombe.

Reported distribution. Carboniferous (Kosanke 1969); Tertiary (Krutzsch 1962); Palaeocene (Krutzsch & Vanhoorne 1977); Miocene (Sontag 1966); Pleistocene (Van Geel & Van der Hammen 1978).

Indeterminate Type 1

Plate 24, fig.10.

Comments. In wall structure and in the presence of an equatorial "suture" this form is morphologically similar to Ovoidites and Schizosporis. It differs in its outline which is triangular with rounded angles and concave sides. The form probably represents another form-genus in this algal group.

Observed distribution. It occurs in association with Schizosporis parvus, S. spriggi, Ovoidites ligneolus and Tetraporina pellucida in the lignites within the Woolwich and Reading Beds at Shorne Wood and Swanscombe.

(iiic) OTHER ALGAL SPECIES RECORDED.

Botryococcus sp.

Crassosphaera sp.

Tasmanites sp.

Pterospermopsis helios
Pterospermella spp.

(iv) MISCELLANEOUS.
Diatoms; plate 24, fig.16,17.
Microforaminiferid test linings (probably reworked).
?Fungal spore; plate 24, fig.14.

CHAPTER 5. DISTRIBUTION OF PALYNOMORPHS IN THE SECTIONS EXAMINED AND BRIEF COMPARISON WITH OTHER EARLY TERTIARY MICROFLORAS.

INTRODUCTION.

In this chapter the results of the quantitative analyses are presented, the microfloral associations which characterise each formation are described and the distribution of selected species is considered in detail.

The quantitative data are summarised in Figs. 5.1-5.17 which show the relative proportions of the most common (or significant) species,or groups of morphologically similar species,through each section. Tables A2.1-A2.10, in Appendix 2, give the actual percentage occurrence of individual species in each sample studied.

Figs. 5.1-5.17 also show the relative proportions of spores/pollen to microplankton/algae within the total microflora. On the whole the microplankton percentages I record are lower than those given for similar sections by dinoflagellate workers (Downie et al. 1971, Eaton 1976, Denison 1977). Furthermore, acritarchs usually form a higher percentage of the microplankton in my material. This may be a result of the preparation technique, where microplankton workers have concentrated the larger dinoflagellate cysts by use of micromesh sieves, but at the expense of smaller acritarchs and pollen.

As explained in Chapter 2, it must be emphasised that these results are based on counts of only 250 spores/pollen from each sample (and on variable numbers of microplankton/algae). Although they adequately show the relative abundance of the commoner species the counts are not large enough to distinguish variations between rarer species, those below 2%, i.e. less than 5 specimens in 250. I do not consider the actual percentage recorded for these species to be significant and have therefore taken all occurrences of less than 2% simply as an indication that the species is present in the sample.

The following descriptive terms are used in the discussion below: rare = less than 2%; fairly common = 2-4.9%; common = 5-14.9%; very common 15-30%; abundant = greater than 30%.

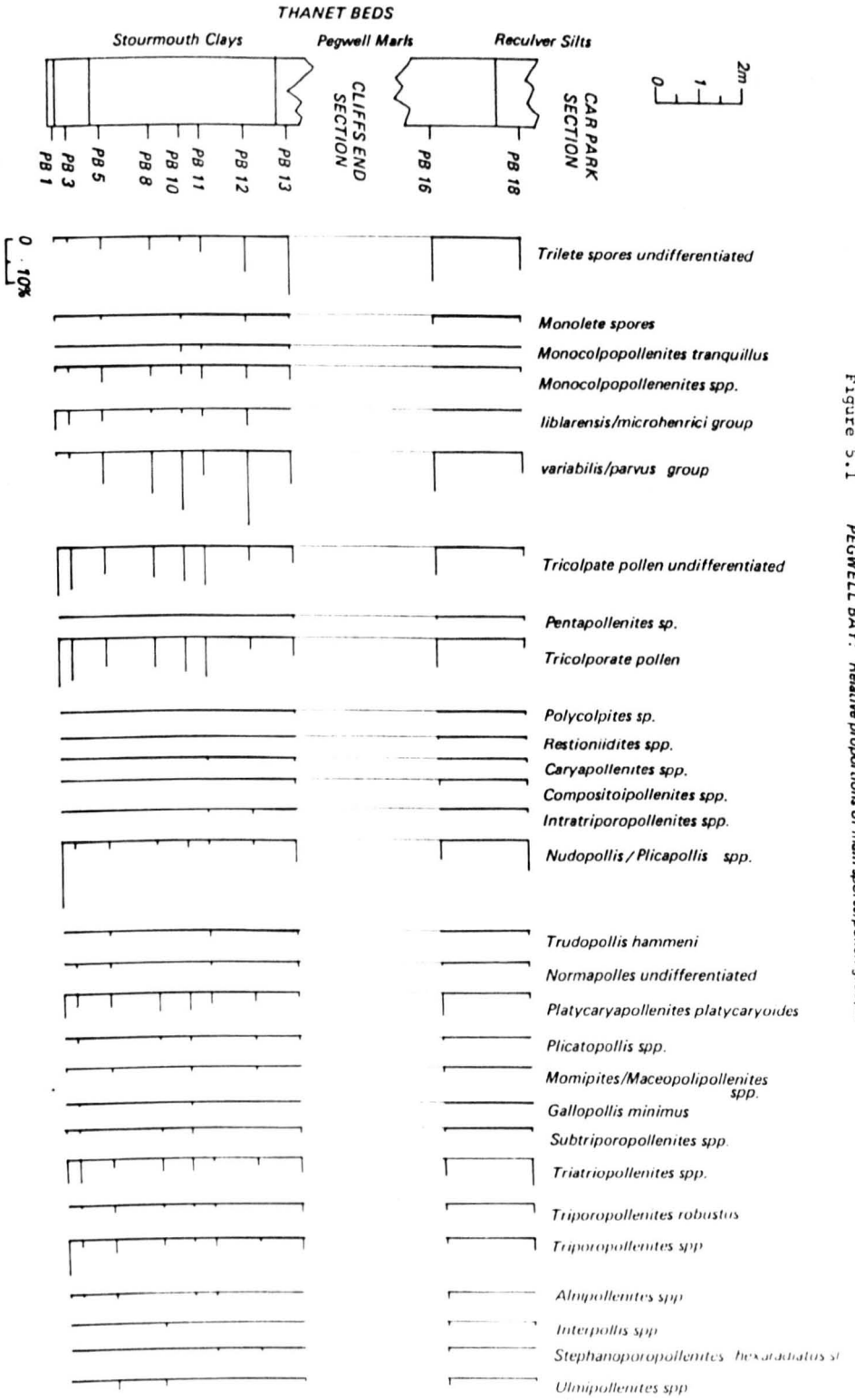


Figure 5.1 *PEGWELL BAY: Relative proportions of main spores/pollen groups.*

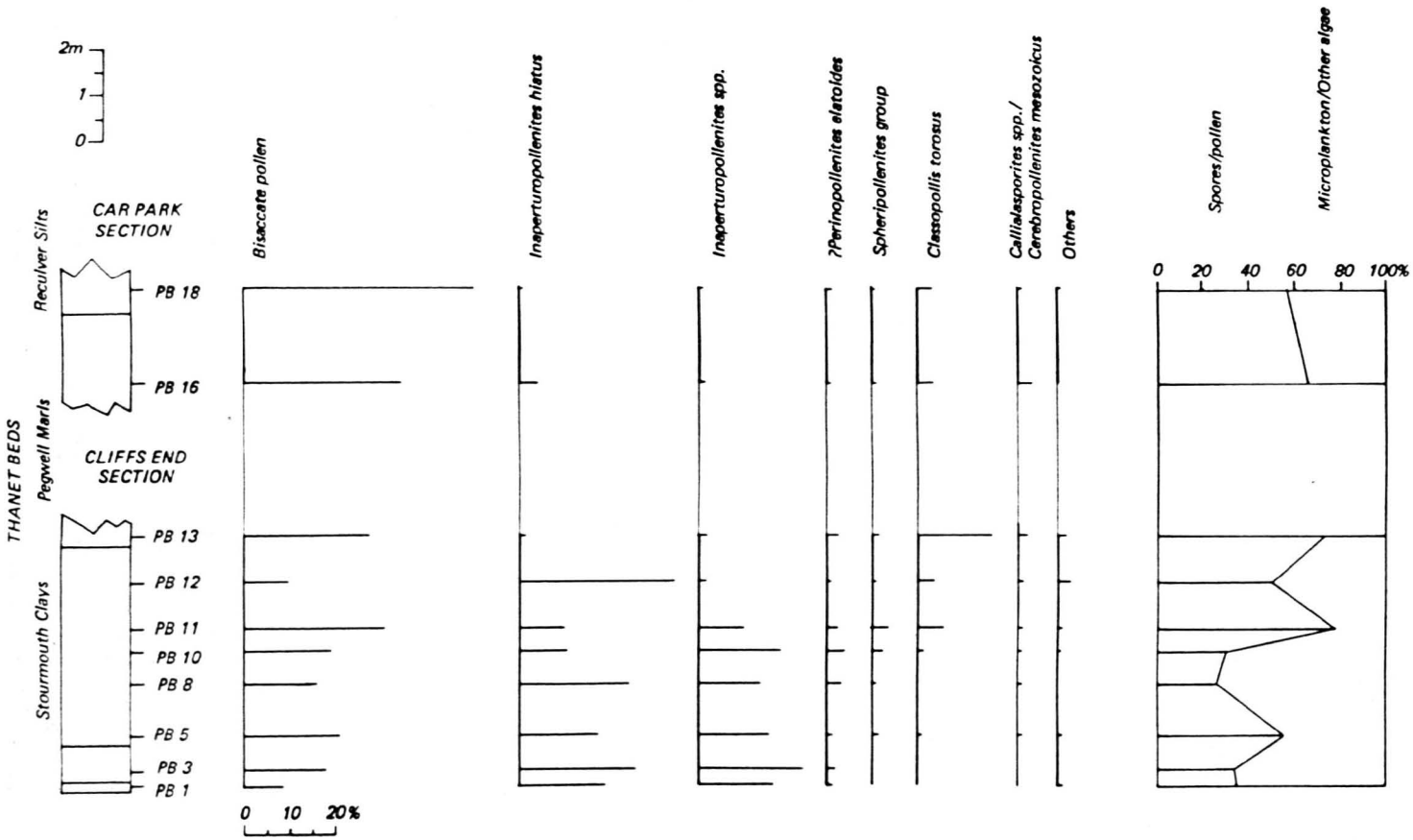


Figure 5.1 *PEGWELL BAY: Relative proportions of main spore/pollen groups*

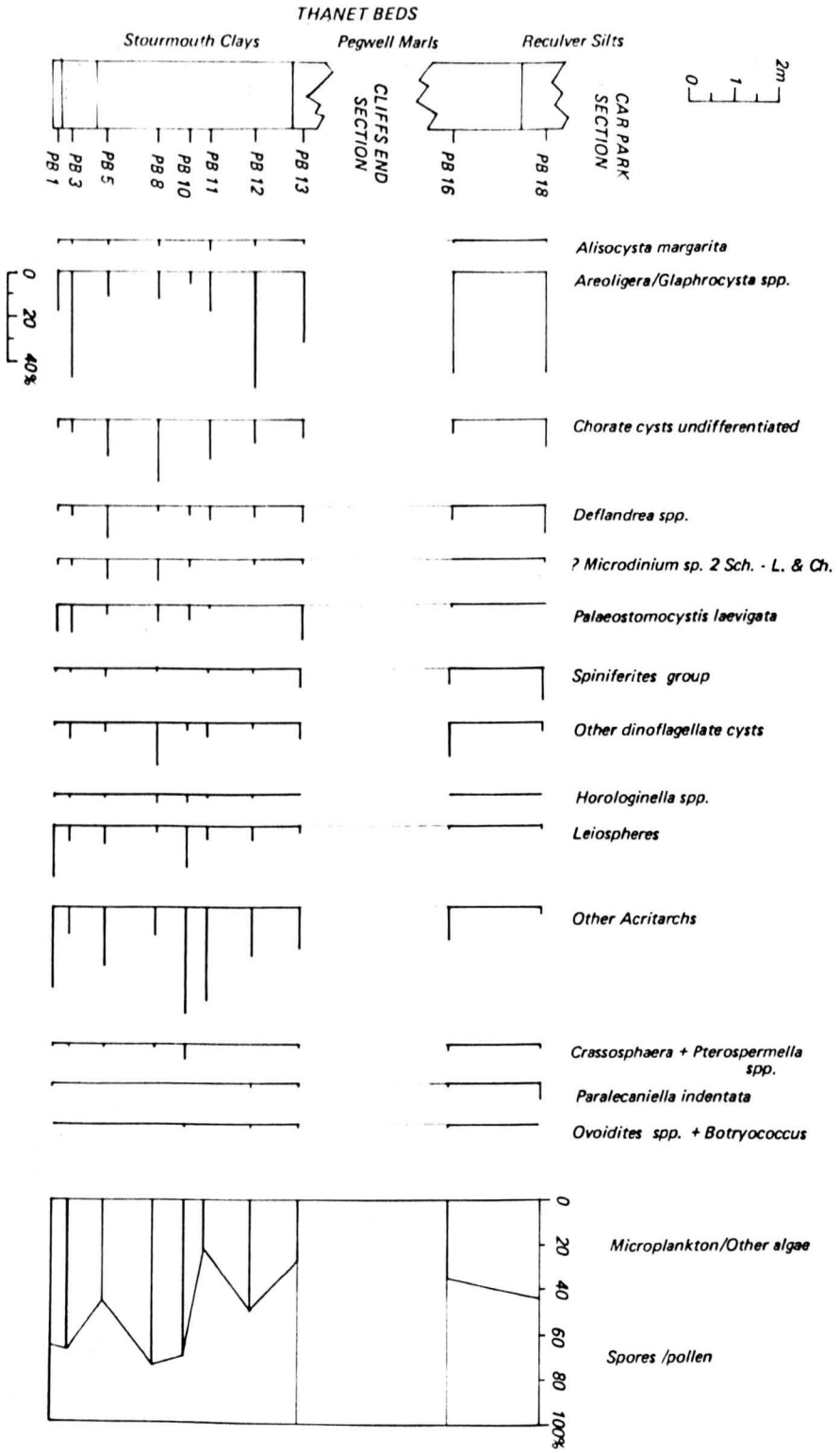


Figure 5.2 *PEGWELL BAY: Relative proportions of main groups of microplankton/algae.*

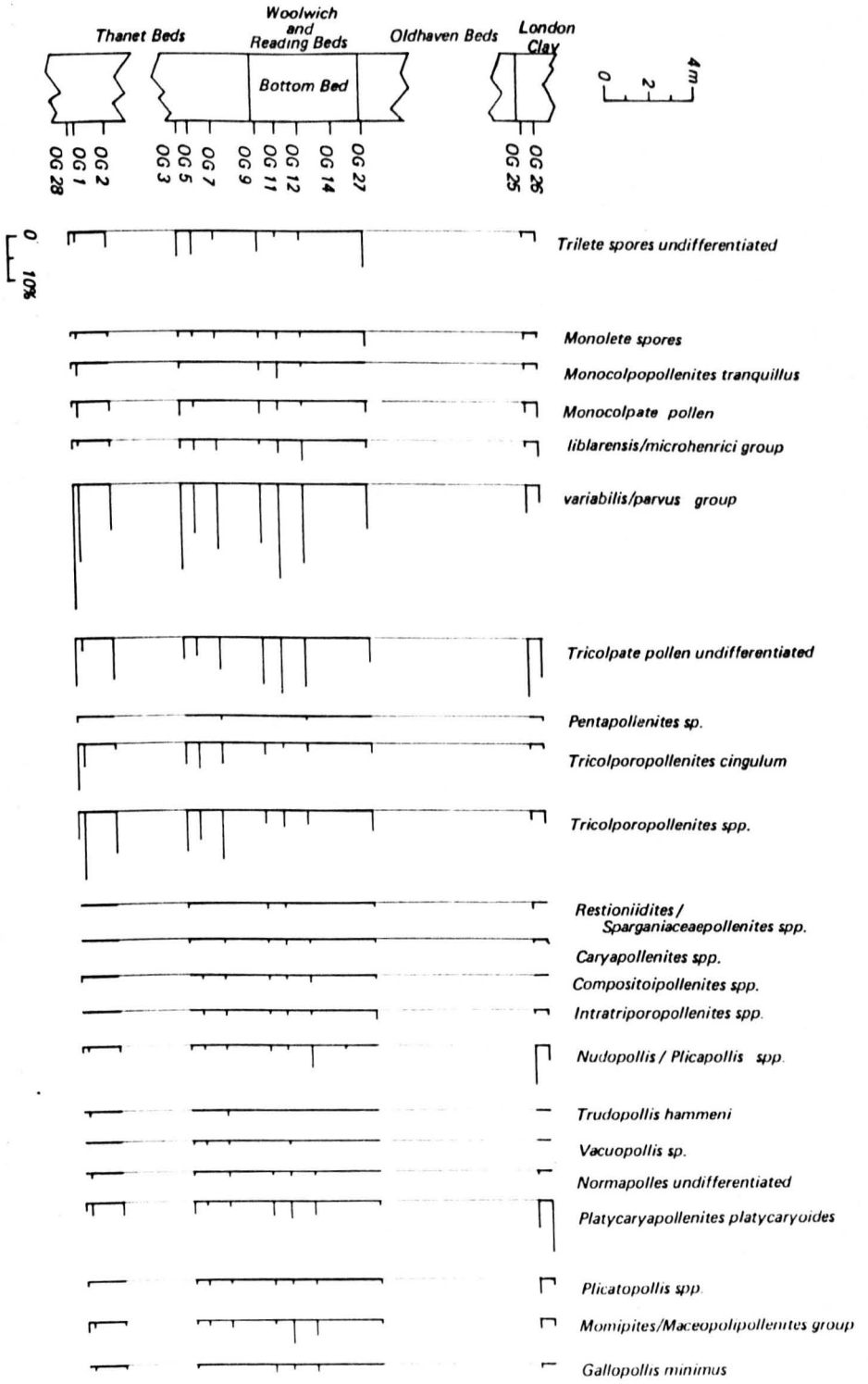


Figure 5.3 *OLDHAVEN GAP: Relative proportions of main spore/pollen groups.*

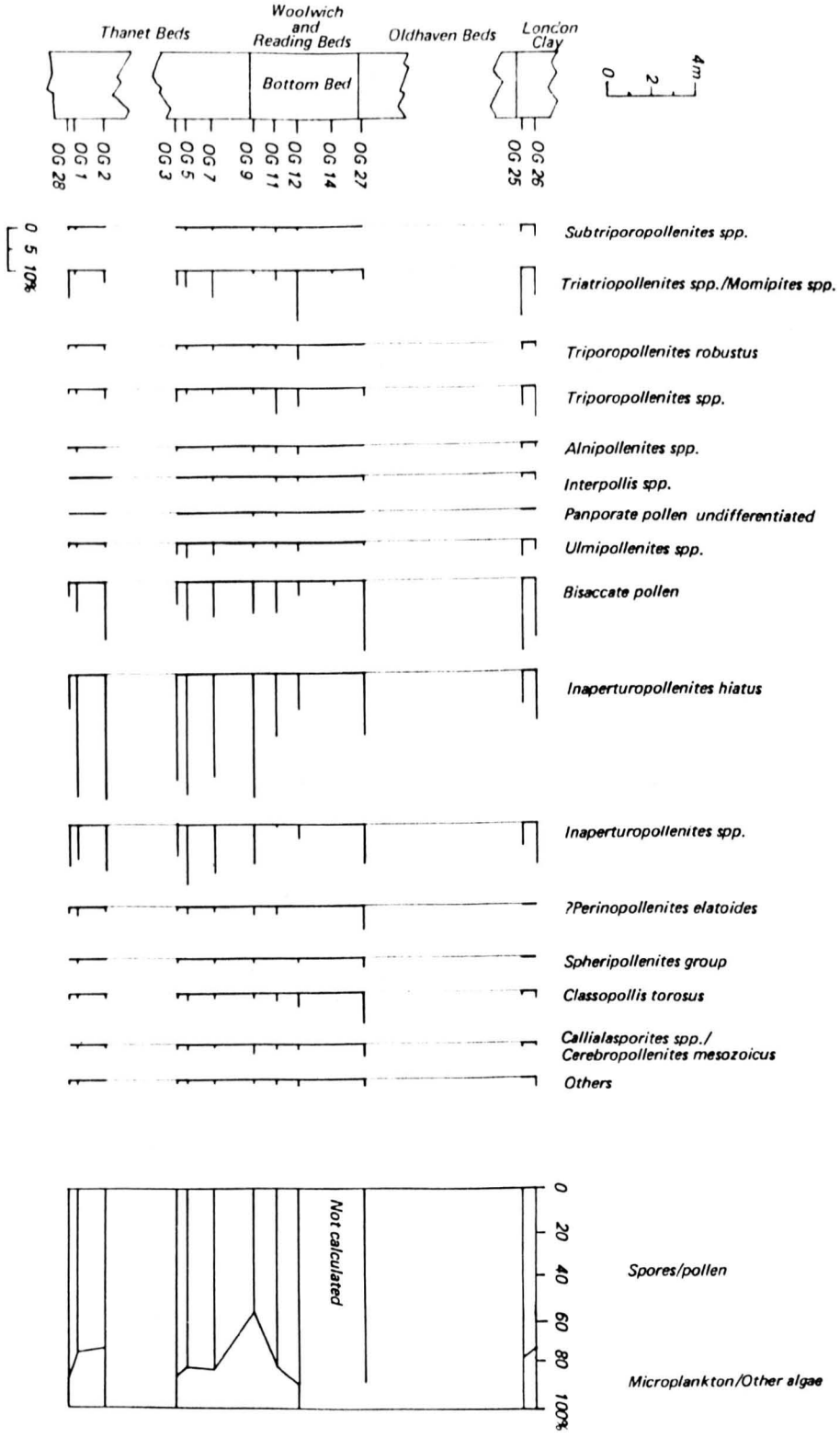


Figure 5.3 *OLDHAVEN GAP: Relative proportions of main spore/pollen groups.*

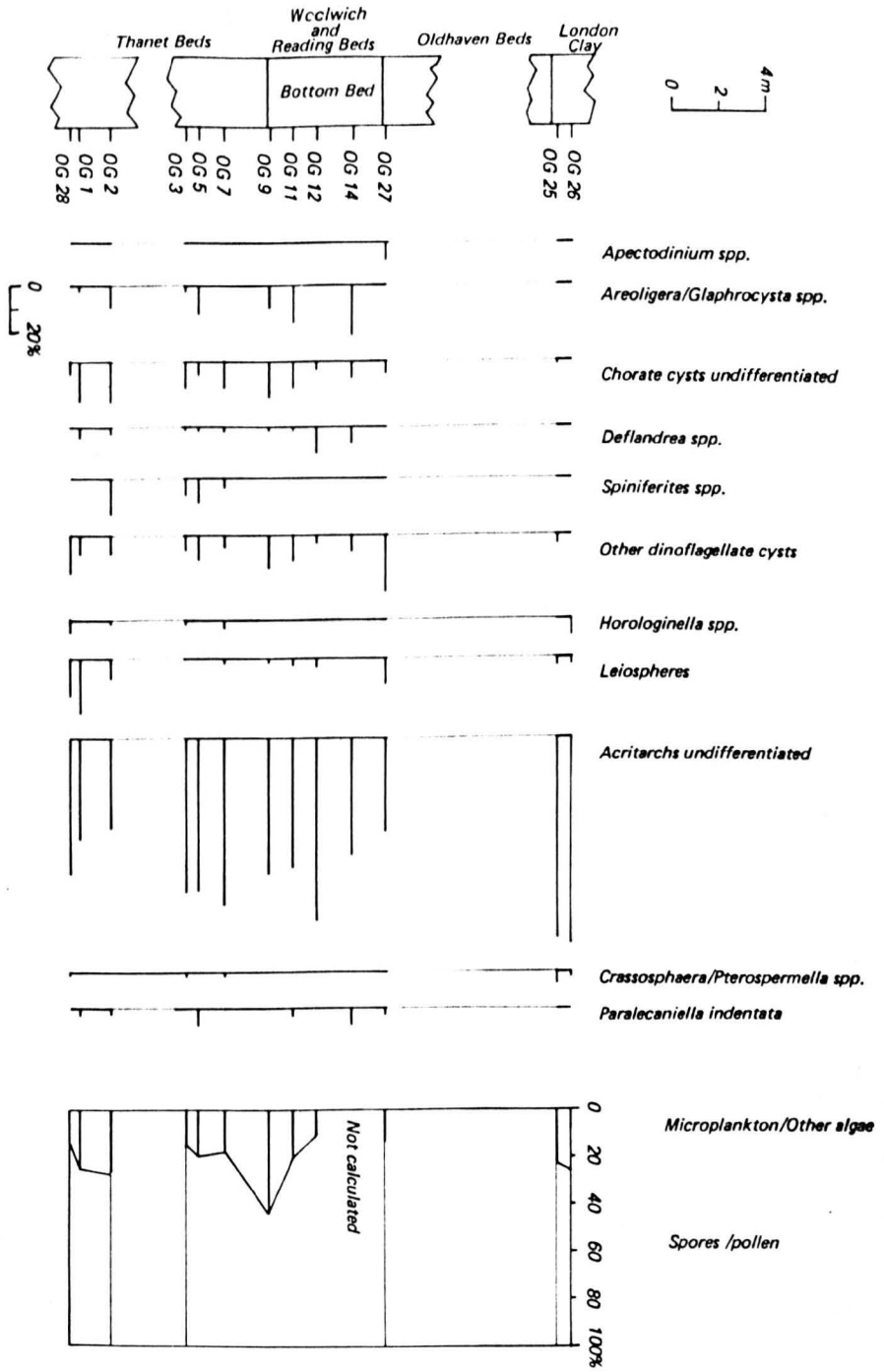


Figure 5.4 *OLDHAVEN GAP: Relative proportions of main groups of microplankton/algae.*

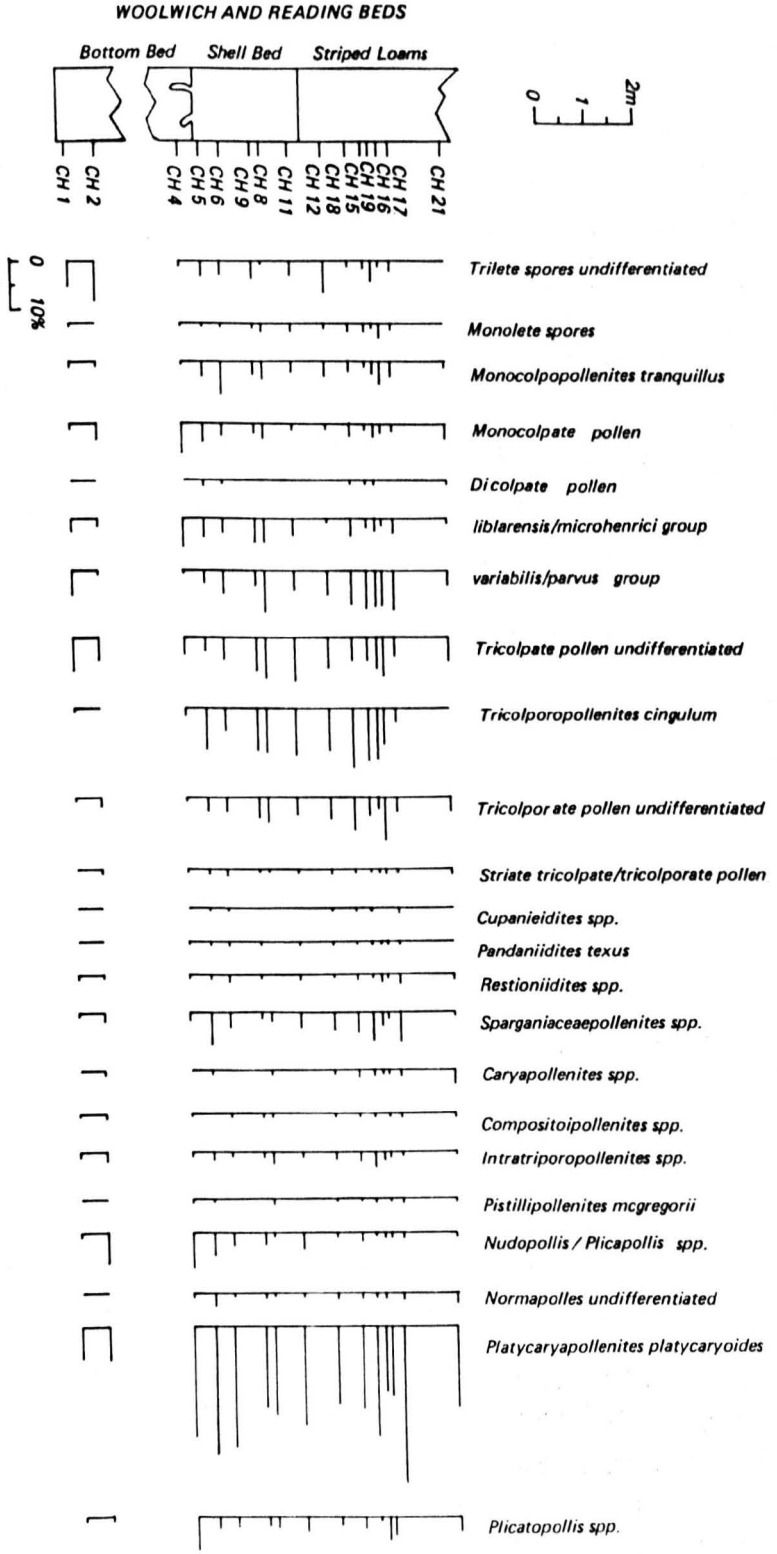


Figure 5.5 *CHARLTON: Relative proportions of main spore/pollen groups.*

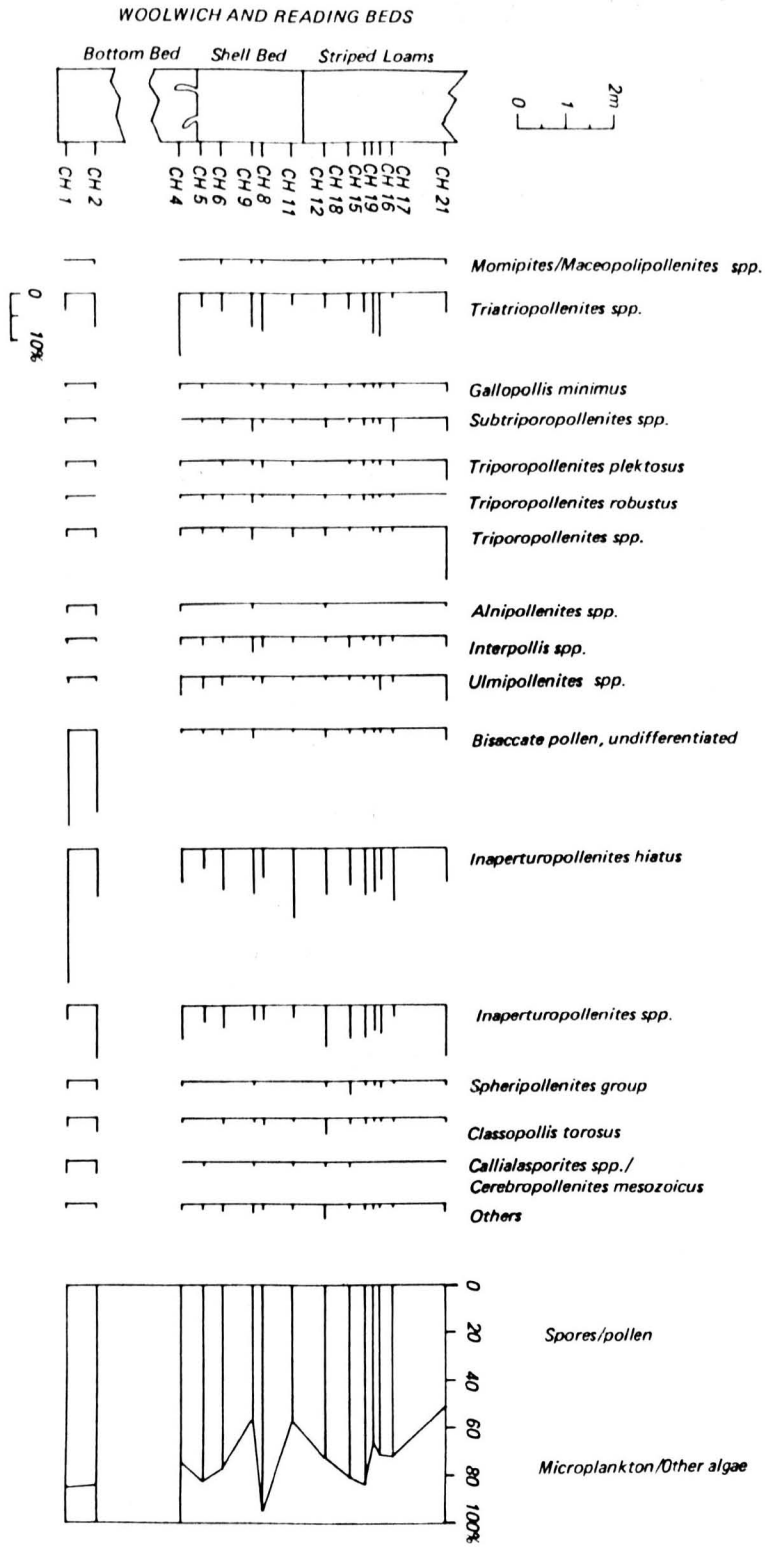


Figure 5.5 *CHARLTON: Relative proportions of main spore/pollen groups.*

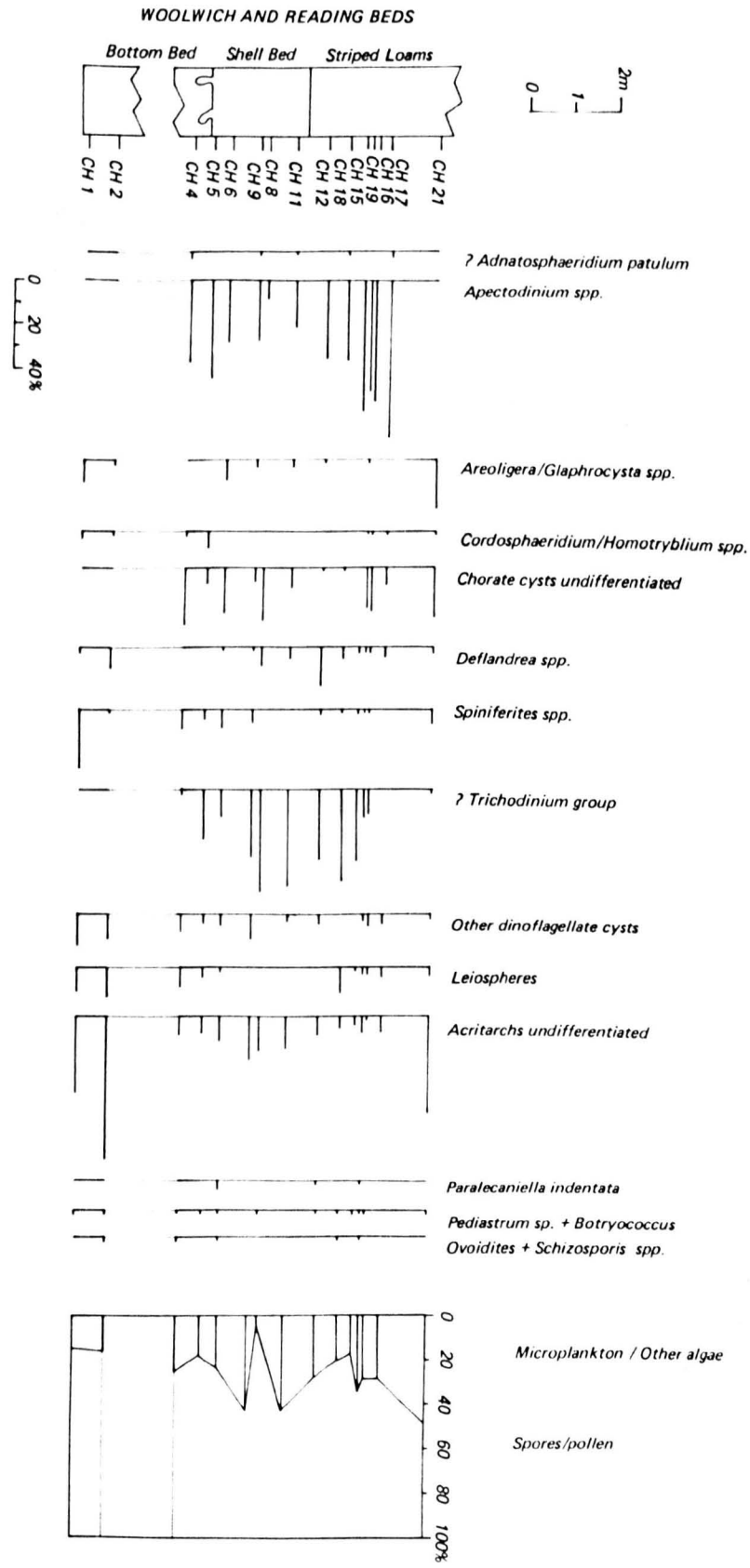


Figure 5.6 CHARLTON: Relative proportions of main groups of microplankton/algae.

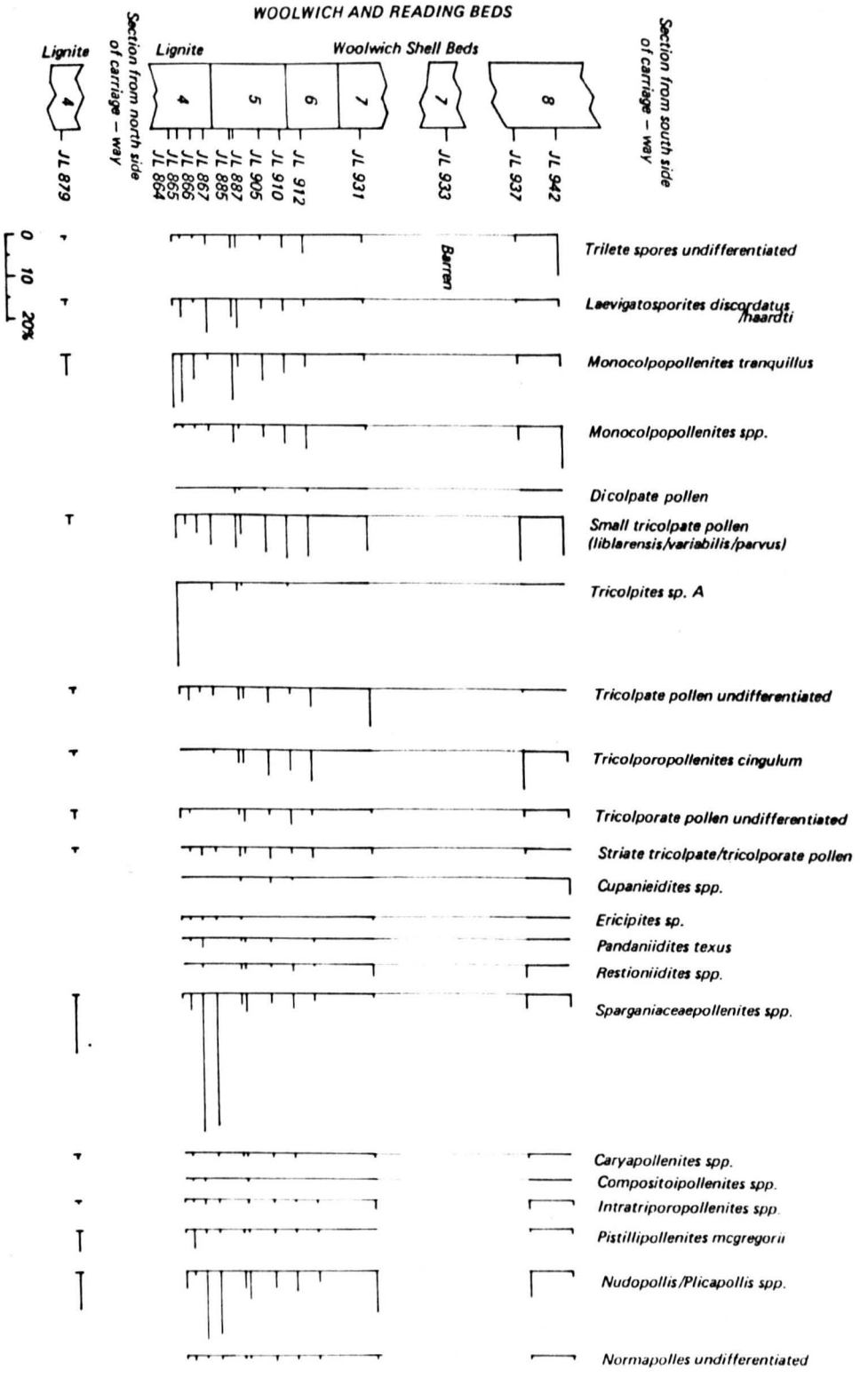


Figure 5.7 SHORNE WOOD: Relative proportions of main spore/pollen groups.

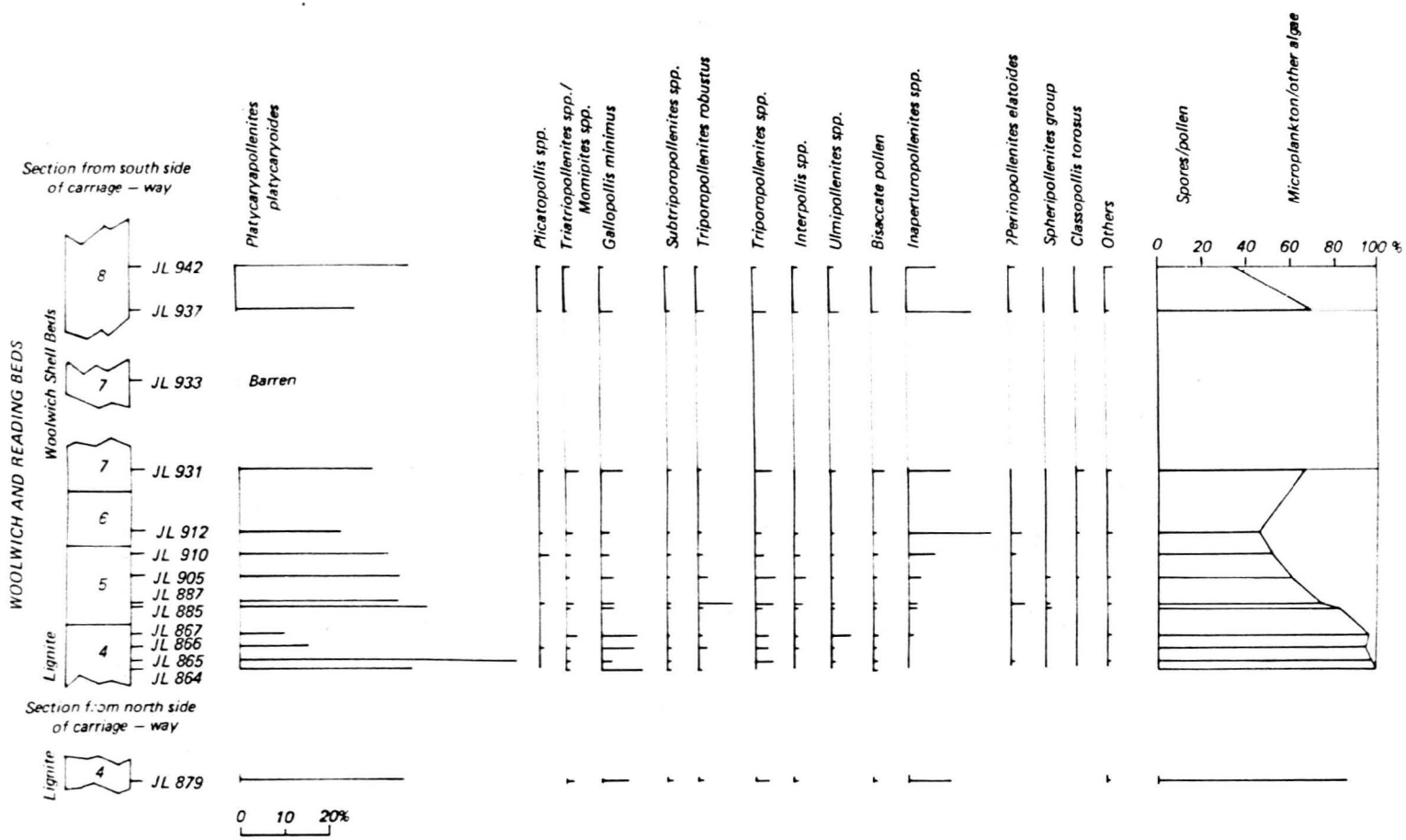


Figure 5.7 *SHORNE WOOD: Relative proportions of main spore/pollen groups.*

Figure 5.8 **SHORNE WOOD: Relative proportions of main microplankton/algal groups.**

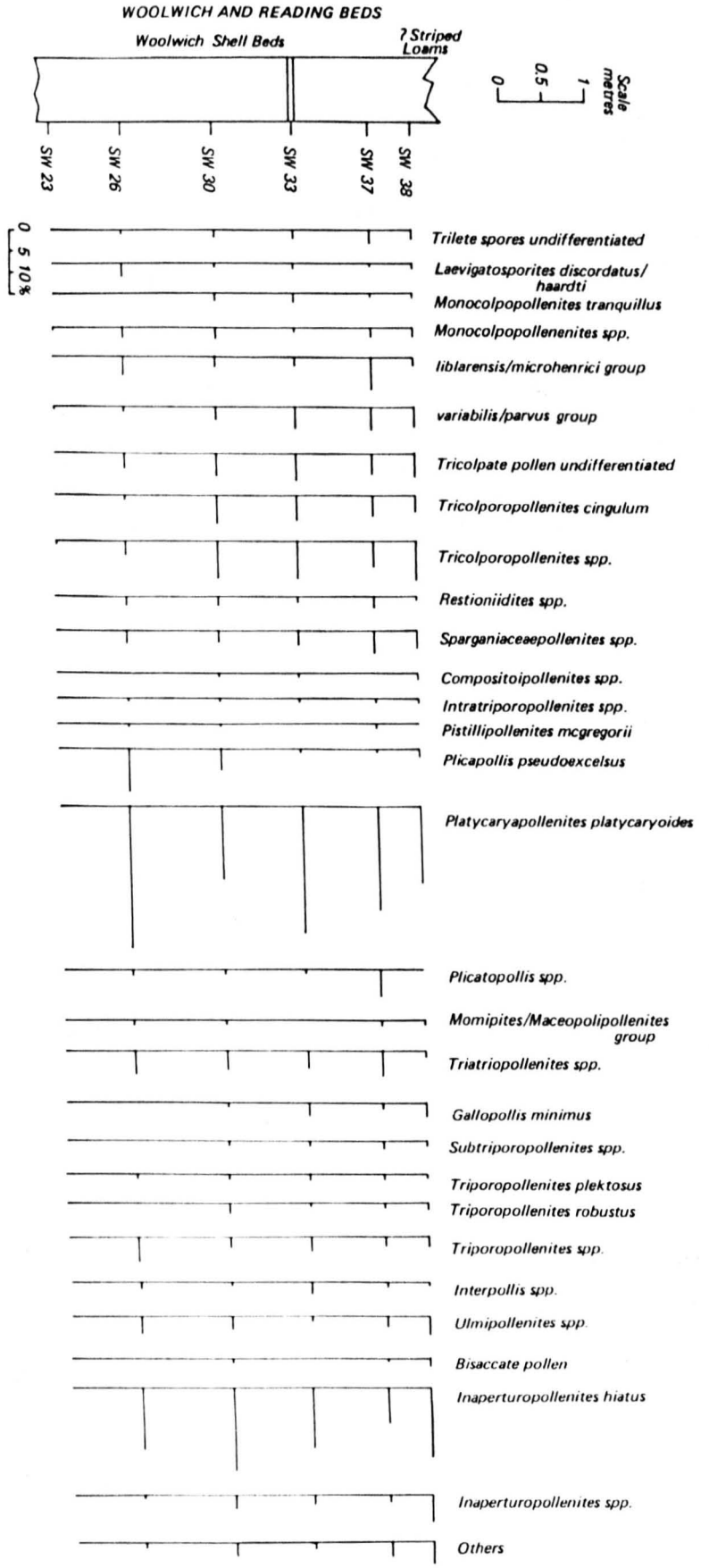


Figure 5.9 *SWANSCOMBE: Relative proportions of main spore/pollen groups.*

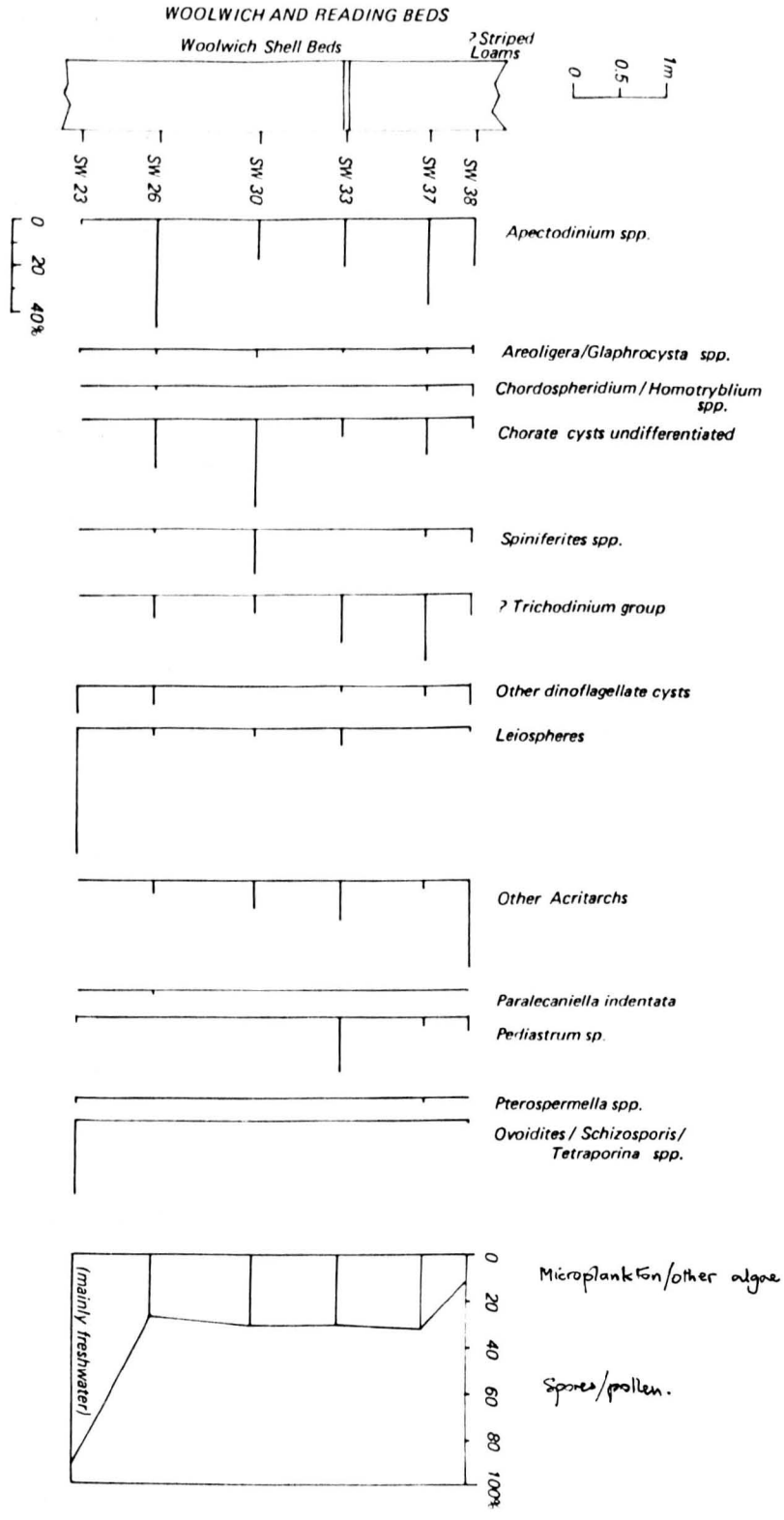


Figure 5.10 *SWANSCOMBE: Relative proportions of main groups of microplankton/algae.*

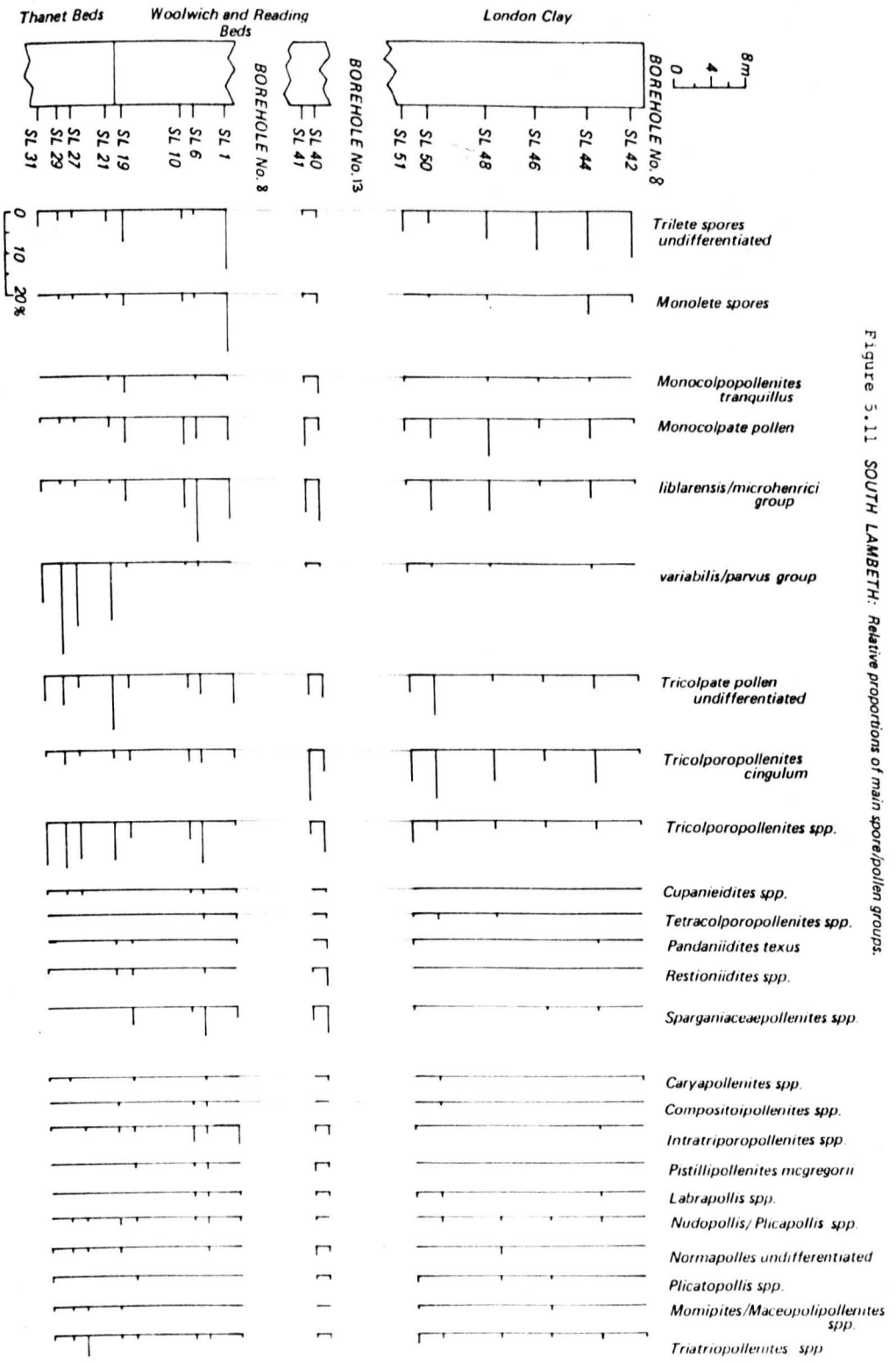


Figure 5.11 SOUTH LAMBETH: Relative proportions of main spore/pollen groups.

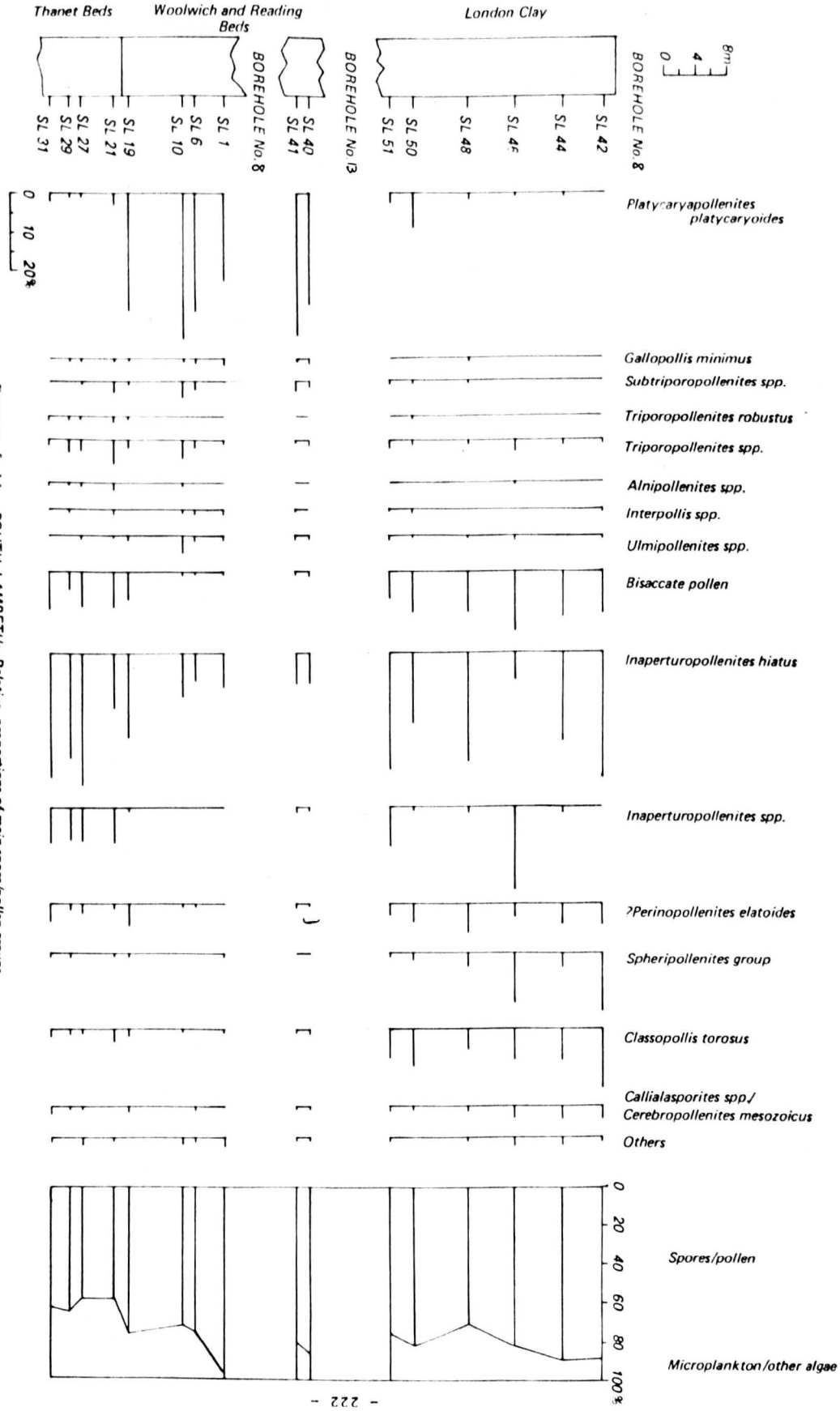


Figure 5.11 *SOUTH LAMBETH: Relative proportions of main spore/pollen groups.*

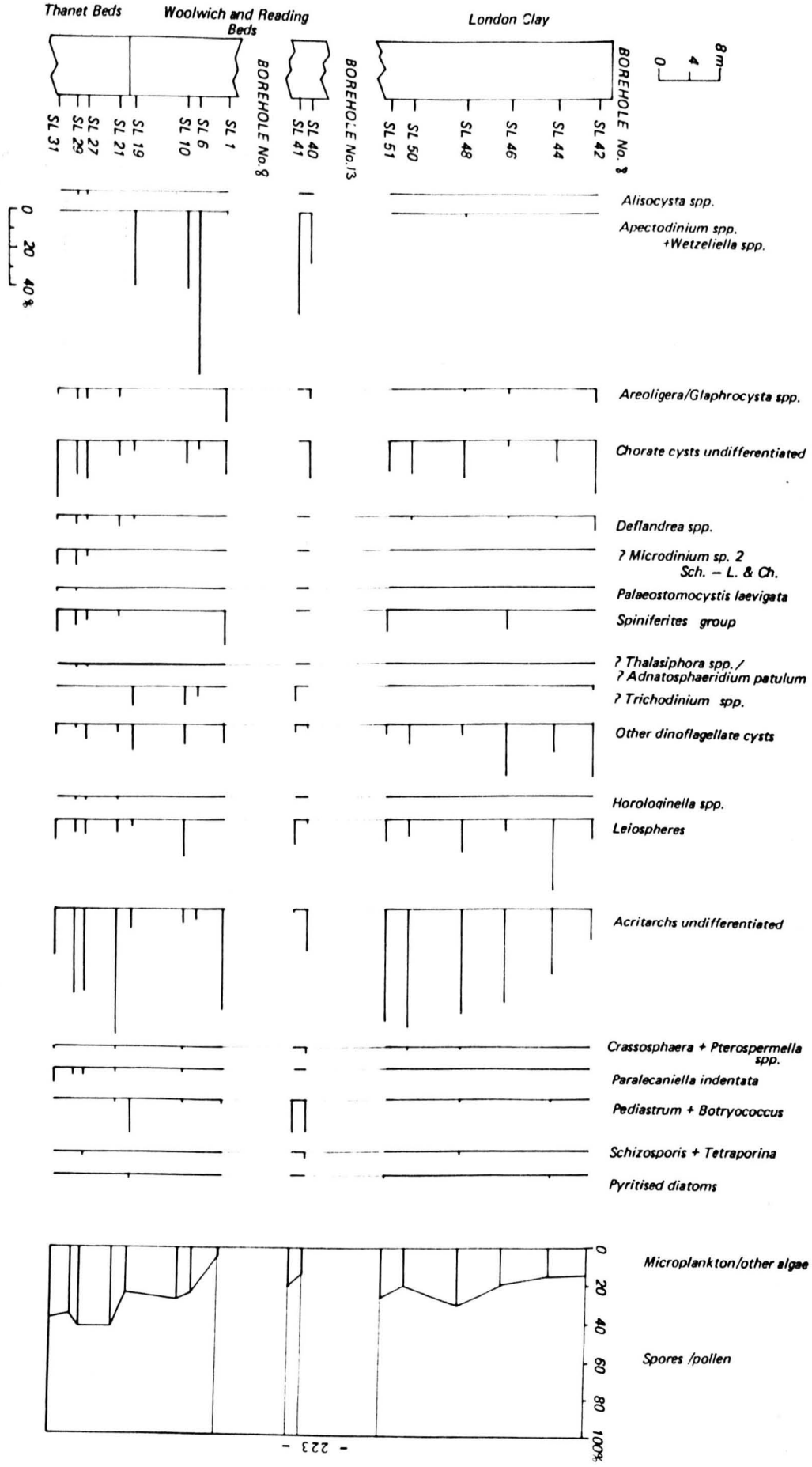


Figure 5.12 *SOUTH LAMBETH: Relative proportions of main groups of microplankton/algae*

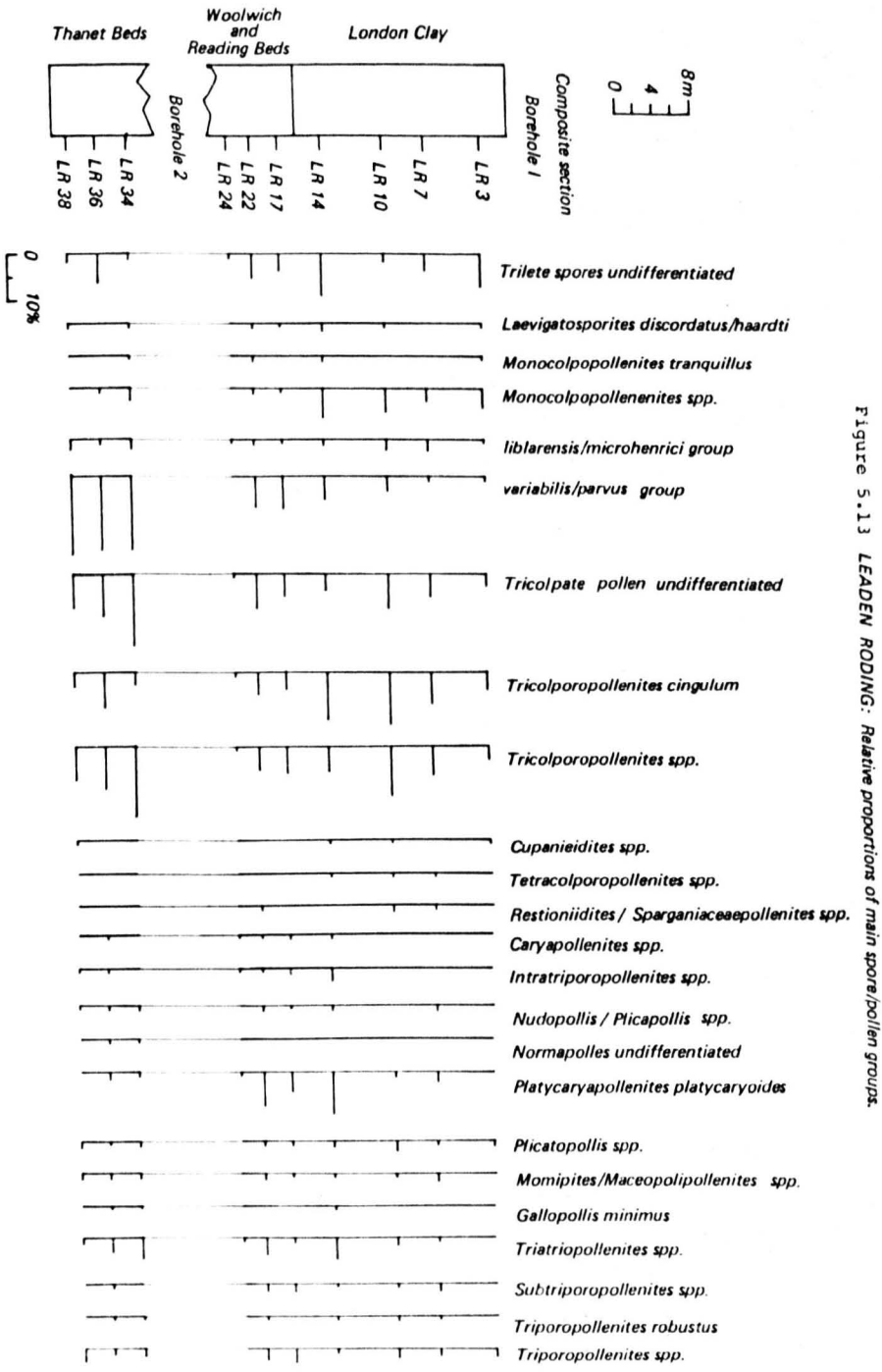


Figure 5.13 *LEADEN RODING: Relative proportions of main spore/pollen groups.*

Figure 5.13 **LEADEN RODING**: *Relative proportions of main spore/pollen groups.*

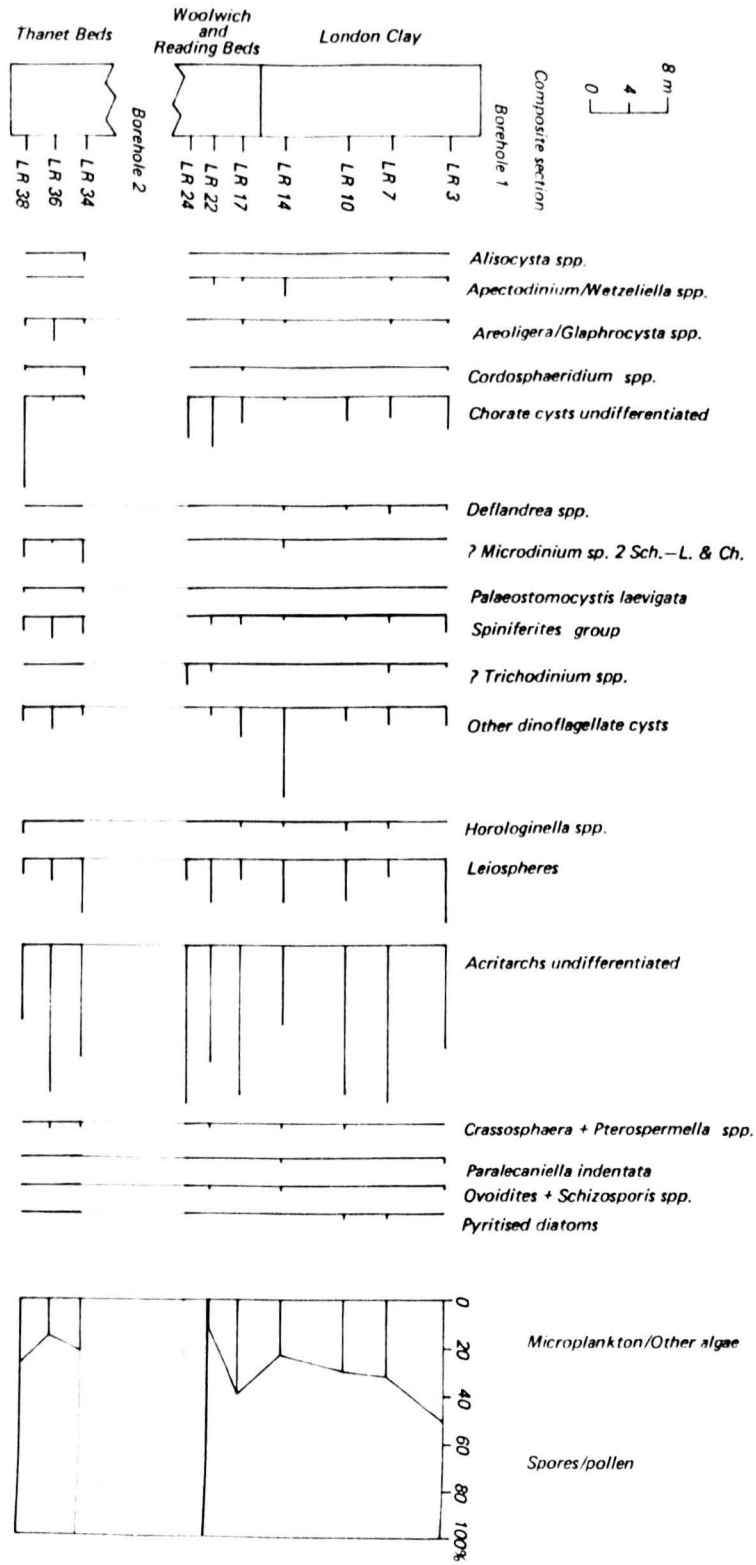


Figure 5.14 *LEADEN RODING: Relative proportions of main groups of microplankton/algae.*

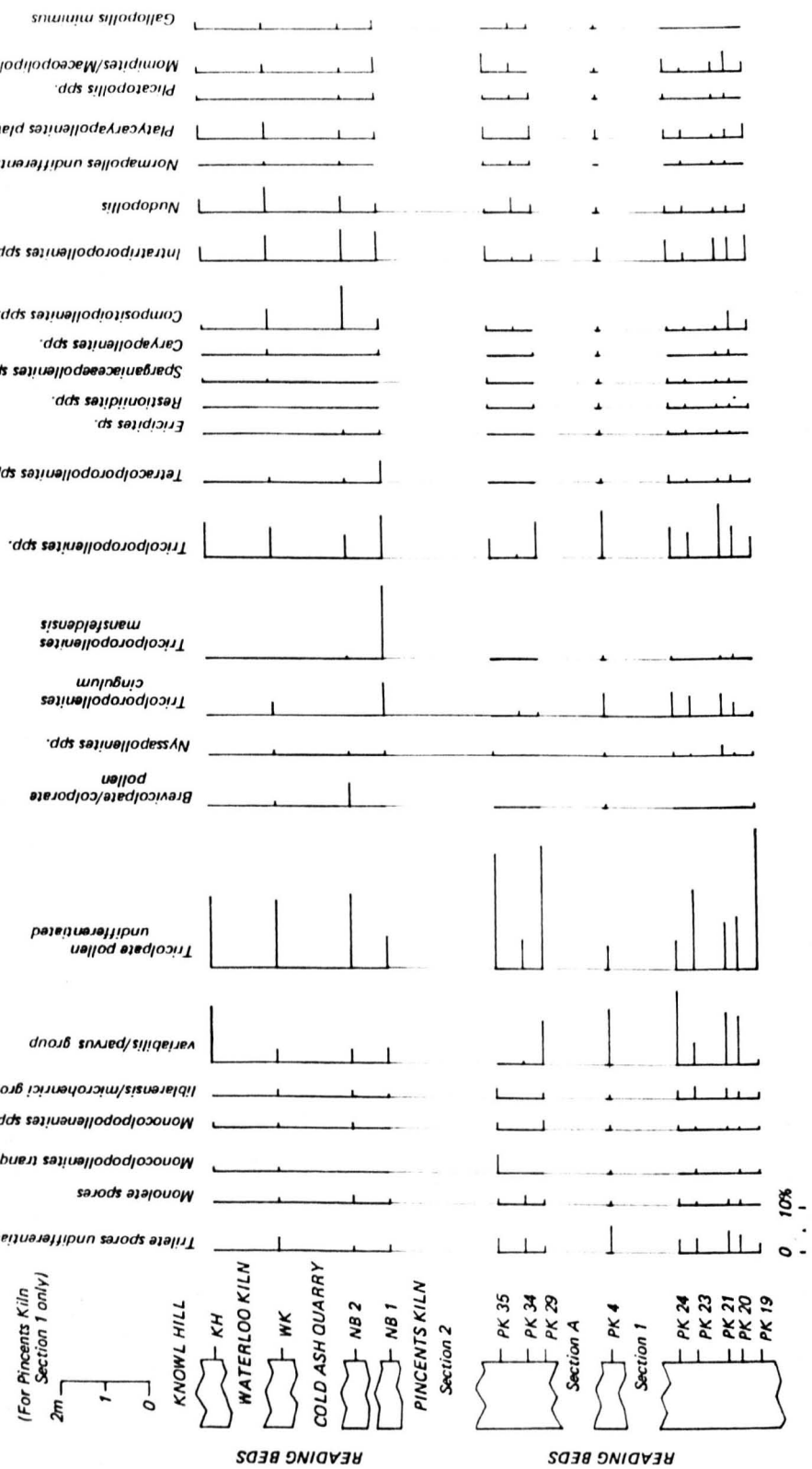


Figure 5.15 *SECTIONS AT THE WESTERN END OF THE LONDON BASIN: Relative proportion of main spore/pollen groups.*

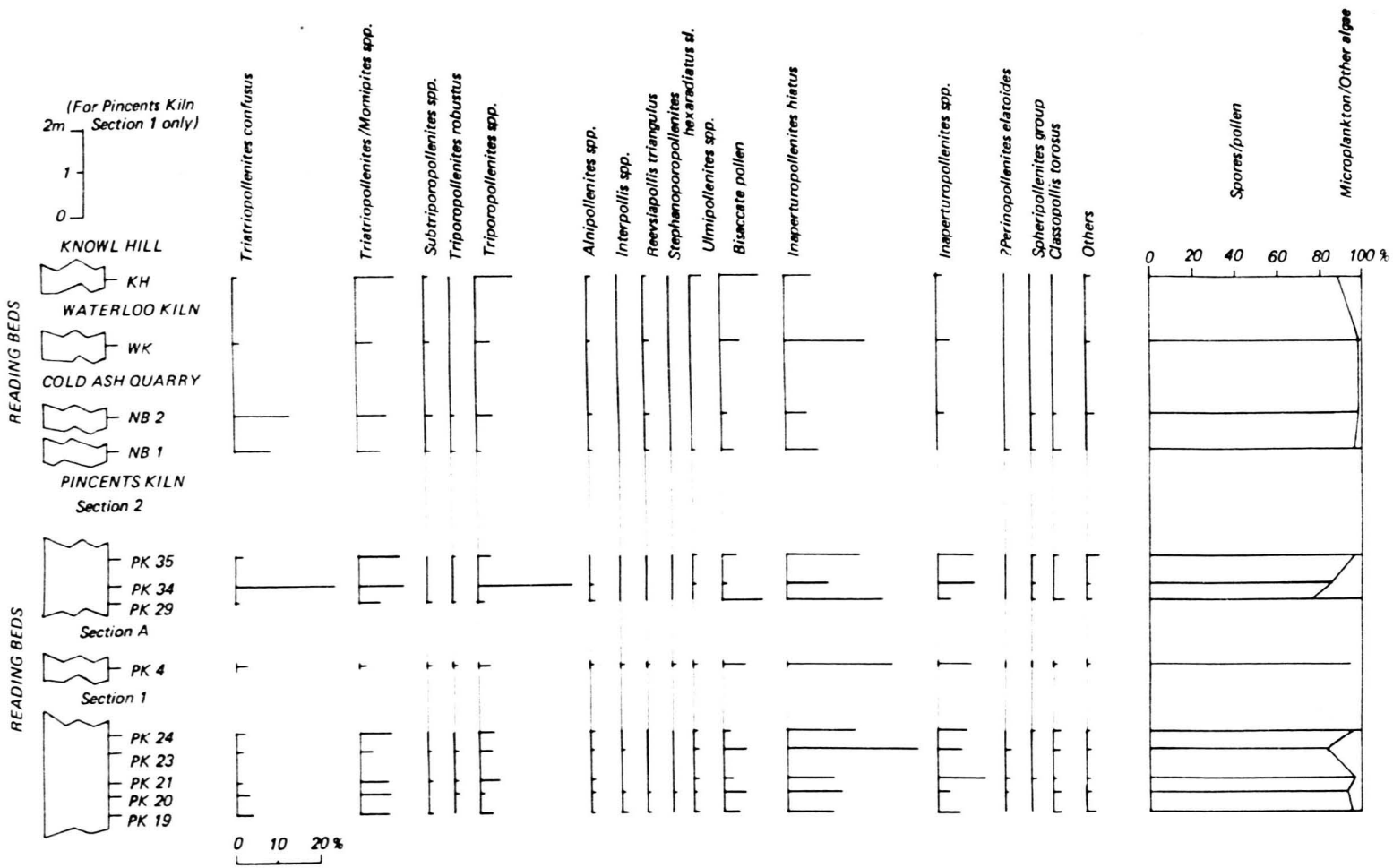


Figure 5.15 *SECTIONS AT THE WESTERN END OF THE LONDON BASIN:*
Relative proportions of main spore/pollen groups.

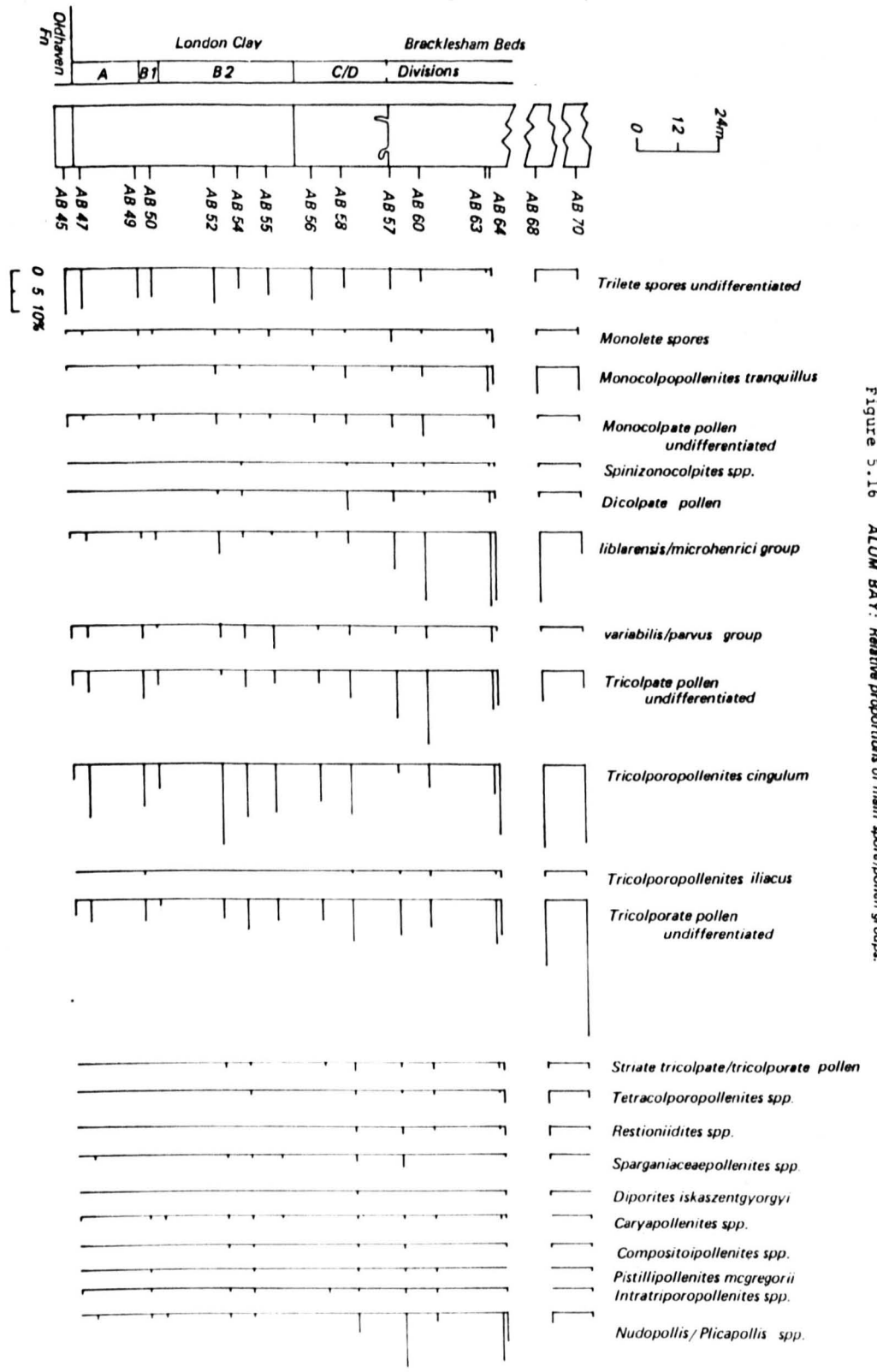


Figure 5.16 *ALUM BAY: Relative proportions of main spore/pollen groups.*

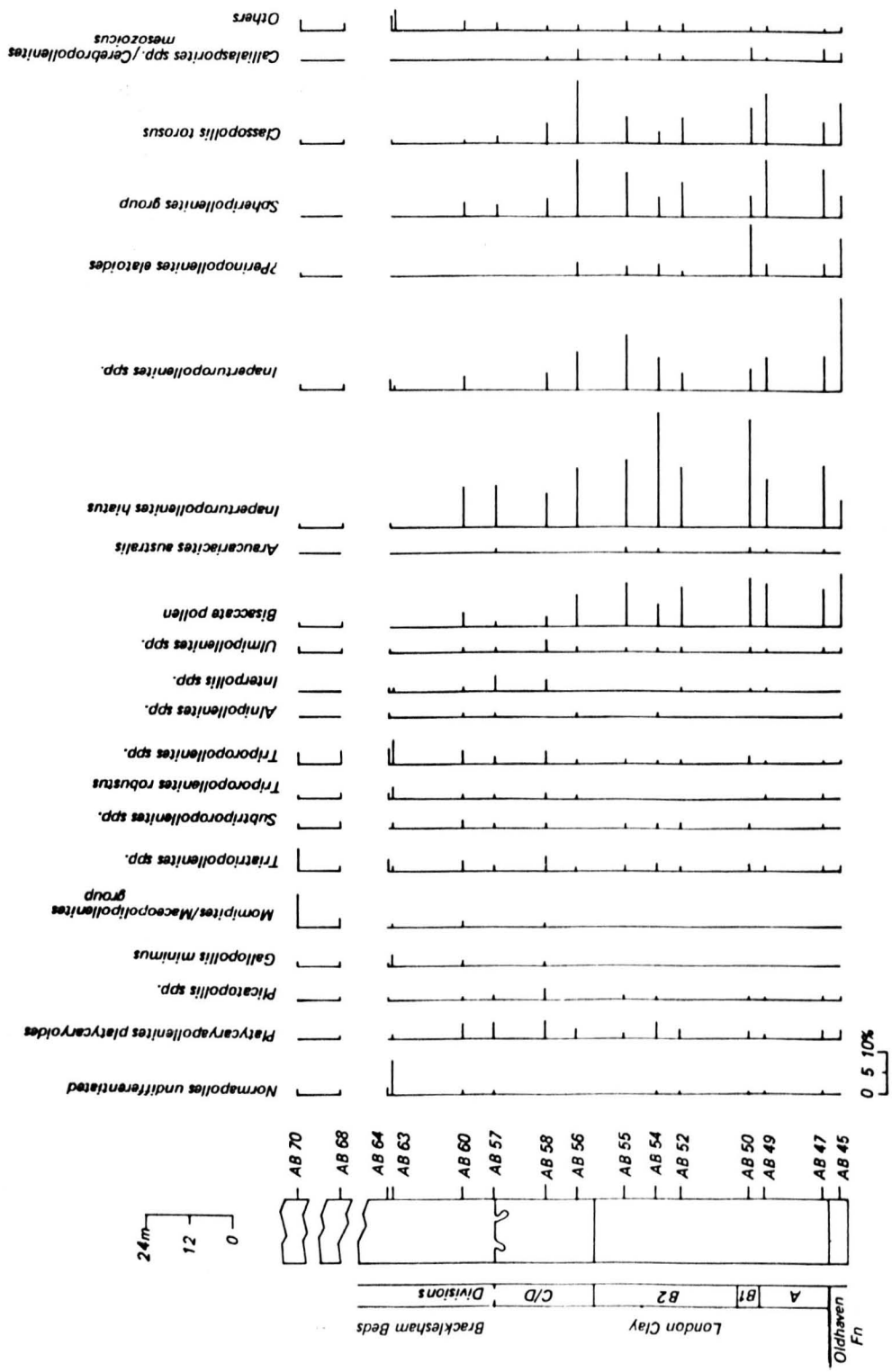


Figure 5.16 *ALUM BAY: Relative proportions of main spore/pollen groups.*

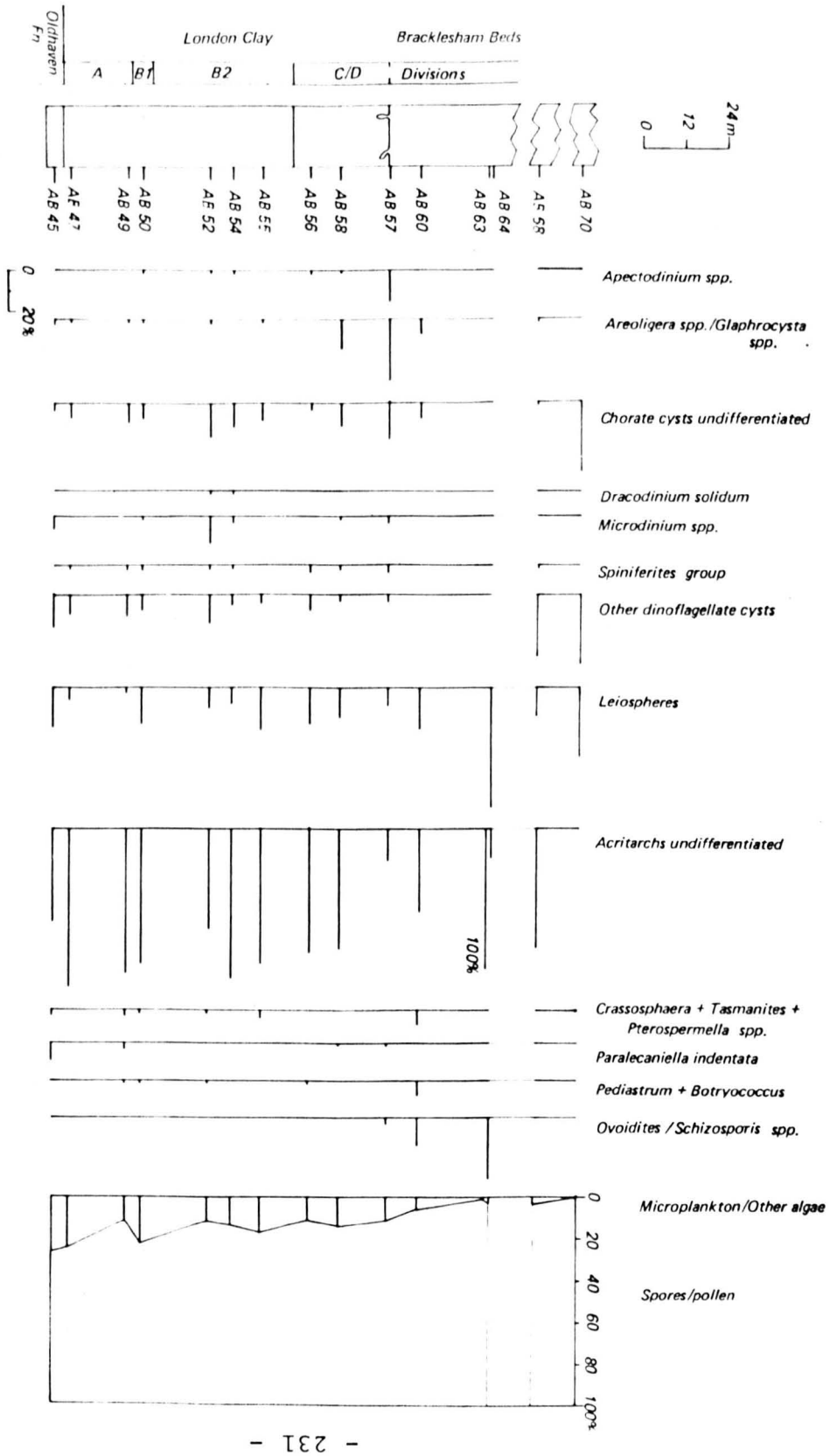


Figure 5.17 **ALUM BAY. Relative proportions of main groups of microplankton/algae.**

5.1 MICROFLORAL ASSOCIATIONS

Although most of the palynomorphs reported from the early Tertiary of the London Basin are long-ranging it is possible to recognise several distinct microfloral associations based on the relative abundance of different taxa. I use the term microfloral assemblage to refer to the total microfloral content of an individual sample. Each microfloral association comprises a group of assemblages which are generally similar in the relative proportions of the common forms and in the presence of rarer but significant species. In most cases the microfloral association coincides with a lithological unit. e.g. the Thanet Beds, the lignite within the Woolwich and Reading Beds, the Reading Beds etc.

The following microfloral associations are recognised:

Thanet Beds: Alisocysta/?Microdinium Association (A/M).

Woolwich Bottom Bed: Areoligera/Glaphrocysta + Deflandrea Assocation (A/G+D).

Woolwich and Reading Beds, Lignite: Platycaryapollenites platycaryoides/Sparganiaceaepollenites spp. Association (P/S).

Woolwich Shell Beds and Striped Loams: Platycaryapollenites platycaryoides/Apectodinium spp./?Trichodinium spp. Association (P/A/T).

Reading Beds: Momipites spp./Intratriporopollenites spp. Association (M/I).

London Clay: Classopollis torosus (reworked) Association (C(R)).

London Clay and basal Bracklesham Beds; Dicolpopollis spp./ Spinizonocolpites spp. Association (D/S).

(i) THANET BEDS: Alisocysta/?Microdinium Association (A/M).

This microfloral association is best developed at Pegwell Bay but is also present in the Thanet Beds at Oldhaven Gap, South Lambeth and Leaden Roding (Figs.5.1-5.4 and 5.11, 5.12 and Appendix 2).

Spore/pollen assemblages generally lack diversity and are characterised by common to abundant bisaccate and inaperturate pollen (including Inaperturopollenites hiatus)

with common to very common small tricolpate pollen of the variabilis / parvus group. The triatriate pollen Platycaryapollenites platycaryoides is only rare to fairly common in comparison with the much higher concentrations characteristic of the Woolwich facies of the Woolwich and Reading Beds. The Normapolles, represented by Nudopollis spp. and Plicapollis pseudoexcelsus, are generally rare but occur consistently and are occasionally very common (PB 1). Several long-ranging genera occur in insignificant amounts, Alnipollenites, Caryapollenites, Compositoipollenites, Restoniidites and Subtriporopollenites. One rare species which is characteristic of this assocation is Trudopollis hammenii while very rare Stephanoporopollenites hexaradiatus tribinae and S. hexaradiatus semitribinae occur at Pegwell Bay and South Lambeth.

The accompanying microplankton association is also best developed at Pegwell Bay. Here significant elements are common to abundant Areoligera/Glaphrocysta spp. with rarer Alisocysta margarita, ?Microdinium sp.2 Sch.-L.& Ch. (together with aff. ?Microdinium sp.2), Palaeostomocystis laevigata and Horologinella spp. Deflandrea dartmooria/oebisfeldensis occurs consistently. Not all of these elements are equally well represented in the other sections although the overall association is comparable. Areoligera/Glaphrocysta spp. are never as abundant as at Pegwell Bay while Alisocysta margarita was not recorded at Oldhaven Gap and this species, ?Microdinium sp.2 (sl.) and Palaeostomocystis laevigata only occur in the lower part of the Thanet Beds at South Lambeth.

WOOLWICH AND READING BEDS

Four separate microfloral associations are recognised within the Woolwich and Reading Beds.

(ii) Woolwich Bottom Bed: Areoligera/Glaphrocysta + Deflandrea Association (A/G+D)

Several samples were examined from this unit at Oldhaven Gap, Charlton and Shorne Wood and single samples from South Lambeth (SL 19) and Leaden Roding (LR 24).

This is the least distinctive of the microfloral

associations recognised from the London Basin having a spore/pollen association very similar to that in the Thanet Beds and a non-diagnostic microplankton association. Thus spore/pollen assemblages are characterised by common to very common bisaccate and inaperturate pollen, fairly common tricolpate pollen of the variabilis/parvus group and minor amounts of long-ranging genera. The microplankton assemblages comprise abundant acritarchs, common to very common Areoligera/Glaphrocysta spp. and fairly common Deflandrea spp. (including D. dartmooria/oebisfeldensis) but generally lack the species which are characteristic of the Thanet Beds association. The presence of ?Microdinium sp.2 Sch.-L. & Ch. at the base of the Woolwich Bottom Bed at Charlton (CH 1) is probably the result of reworking.

Samples CH 4 and SL 19 are much more similar to the overlying Woolwich Shell Beds assocation with very common or abundant Platycaryapollenites platycaryoides and abundant Apectodinium spp. The assemblage in LR 24 is too sparse to count but ?Trichodinium sp. is present suggesting that this also is a transitional assemblage. Similarly, samples from Shorne Wood, JL 856, JL 858 and JL 863, contain very rare palynomorphs but include Apectodinium parvum near the top of the unit, at JL 863.

(iii) Woolwich and Reading Beds, Lignite: Platycaryapollenites platycaryoides/Sparganiaceaepollenites spp. Association (P/S).

This microfloral association is only present at Shorne Wood, in the Lignite beneath the Woolwich Shell Beds, and probably represents a local microflora i.e. one that was deposited at or near to the site of pollen/spore production (see discussion below, 5.2).

Assemblages lack diversity but, in contrast to the Thanet Beds and Woolwich Bottom Bed associations, contain only very rare bisaccate and inaperturate pollen. Amongst the angiosperm pollen, porate forms are much more common and diverse than the tricolpate and tricolporate species. The association is characterised by an abundance of Platycaryapollenites platycaryoides (JL 864, JL 865 and

JL 879) with abundant Sparganiaceaepollenites spp. (at JL 866 and JL 867). Less common but noticeable elements include Laevigatosporites haardti, L. discordatus, Monocolpopollenites tranquillus, Pistillipollenites mcgregorii, Nudopollis spp. and Plicapollis pseudoexcelsus, and Gallopollis minimus.

The only algae recorded are rare specimens of Ovoidites ligneolus, Schizosporis parvus, S. spriggi, Tetraporina pellucida and Indeterminate No. 1, all of which probably have affinity with the Zygnemataceae and are of freshwater origin. The leiospheres also are most probably freshwater algae.

The lignitic horizon at the base of the Woolwich Shell Beds at Swanscombe (SW 23) appears to be entirely different in origin, the lignitic clasts were probably transported. The associated sands and claystones contain a sparse microflora which includes dinoflagellate cysts (Apectodinium sp.) as well as leiospheres of unknown origin, the presumed Zygnemataceae Ovoidites ligneolus, Schizosporis parvus, and S. spriggi and the colonial alga Pediastrum.

(iv) Woolwich Shell Beds and Striped Loams: Platycaryapollenites platycaryoides/Apectodinium spp./?Trichodinium spp. Association (P/A/T).

The Woolwich Shell Beds were examined from Charlton, Shorne Wood, Swanscombe and from the South Lambeth Road Boreholes while the Striped Loams were mainly studied at Charlton.

This is a very distinctive and diverse microfloral association. The most common spores and pollen are the same as those which dominate the lignite at Shorne Wood, however there is considerable diversity in the rarer species and bisaccate and inaperturate pollen become more common again. Platycaryapollenites platycaryoides is generally very common to abundant and dominates assemblages, Sparganiaceaepollenites spp., monocolpate pollen and Laevigatosporites spp. are fairly common while rare but persistent species which are particularly characteristic of this association include Pistillipollenites mcgregorii,

Dicolpopollis spp., Restoniidites spp., Labrapollis labraferus and Subtriporopollenites constans magnus. Pentaporoites belgicus is extremely rare (recorded only at CH 5, CH 8, CH 16, JL 887 and LR 22, see below).

In contast to the microfloral Association P/S (Lignite) dinoflagellate cysts are an important constituent of this association. Apectodinium spp., particularly A. parvum and A. homomorphum, are usually abundant and are accompanied by common to abundant ?Trichodinium spp. Cordosphaeridium spp. and Homotryblium spp. are also characteristic although they are generally rare and chorate cysts (undifferentiated) are sometimes abundant. Acritarchs are never as abundant as in the Thanet Beds and Woolwich Bottom Bed. At some levels the freshwater colonial alga Pediastrum is abundant, probably indicating local influxes of freshwater (e.g. JL 905, JL 942, SW 33).

There are no major changes in the spore/pollen assemblages in the Striped Loams at Charlton. Triporate pollen becomes common at the top of the sequence (CH 21), in the more sandy facies but otherwise assemblages are the same as those through the Shell Beds. There is a change in the microplankton in this same sample however, with the absence of Apectodinium spp. (previously abundant), a marked reduction in ?Trichodinium spp. and a distinct increase in Areoligera/Glaphrocysta spp. and acritarchs (see discussion in Section 5.3).

The Woolwich and Reading Beds in the Leaden Roding Boreholes are mainly of Reading facies (Fig.1.4) and contain rather nondescript assemblages that are similar to those present in the western part of the London Basin, mainly in their low percentages of Platycaryapollenites platycaryoides. It is interesting to note however, that species usually typical of the Woolwich facies also occur here rarely (Tables A2.5, A2.6). These include ?Trichodinium spp., Apectodinium homomorphum, A. parvum, Dicolpopollis spp., Pistillipollenites mcgregorii and Pentaporoites belgicus. This suggests that the boundary of the Intermediate facies of the Woolwich and Reading Beds may be extended slightly further north to include Leaden Roding.

(v) Reading Beds: Momipites spp./Intratriporopollenites spp. Association (M/I).

Samples from the western end of the London Basin, (Pincents Kiln, Cold Ash Quarry, Waterloo Kiln and Knowl Hill) contain assemblages that are moderately diverse in their tricolporate pollen and in the triporate (triatriate) pollen of the Momipites group. The most characteristic features of the association are the very common tricolpate pollen (including the variabilis/parvus group, Tricolporopollenites angululuminosus and T. retiformis), the common and diverse Momipites group (including Maceopollipollenites spp., Momipites coryloides and undifferentiated triatriate pollen) and only rare to fairly common Platycaryapollenites platycaryoides. Compositoipollenites spp. and Intratriporopollenites spp. are more common here than in any other association. In addition there are several species which appear to be of local origin. Their abundance varies considerably from one sample to another and they are not always present. Nonetheless these also are characteristic of this microfloral association. They include Nyssapollenites spp., Tricolporopollenites mansfeldensis, Rhoipites sp. A and Triatriopollenites confusus (see 5.3 below).

Microplankton are extremely rare in this association (Table A2.8) and mainly comprise acritarchs with Areoligera/Glaphrocysta spp., undifferentiated chorate cysts (including Baltisphaeridium sp. B. Gr.-Cav.) and rare Spiniferites spp. (PK 23, PK 24, PK 4).

Spores and pollen are extremely sparse in the samples examined from the M4 Motorway. They are shown as actual numbers, rather than percentages, in Appendix 2 (Table A2.7). Microplankton are generally rare and comprise mainly acritarchs with Areoligera/Glaphrocysta spp. and chorate cysts including Cordosphaeridium spp. (M4/7(1), M4/7(2)).

Oldhaven Beds

This unit was mainly examined at Oldhaven Gap but assemblages are generally too sparse for the recognition

of a distinct microfloral association. The richest sample from the glauconitic sands, OG 22 (not shown in Appendix 2) contains rare bisaccate and inaperturate pollen, smooth trilete spores and Laevigatosporites haardti with reworked Callialasporites dampieri, Lycospora sp. and Classopollis torosus. The microplankton comprises only the acritarchs, Micrhystridium spp. with Paralecaniella indendata which "dominates" the assemblage (30 specimens). OG 27 is atypical, coming from a channel in the base of the Oldhaven Beds. This has a rich microflora which is transitional between the Woolwich Bottom Bed and London Clay. The presence of common small tricolpate pollen, very common bisaccate and inaperturate pollen and low percentages of Platycaryapollenites platycaryoides is characteristic of both associations but the high proportion of reworking in the OG 27 assemblage is more typical of the London Clay. This includes common Classopollis torosus with Cerebropollenites mesozoicus, Callialasporites dampieri, Vitreisporites pallidus, Quadraeculina anellaeformis and Lycospora sp. (see Table A2.1, Appendix 2). Microplankton are comparatively sparse but do include Apectodinium homomorphum and A. parvum which usually characterise the Woolwich facies of the Woolwich and Reading Beds, together with Deflandrea dartmooria/oebisfeldensis and Hafniasphaera sp. The presence of Nannoceratopsis gracilis is further evidence of the reworking of early-middle Jurassic material.

The single sample from the Oldhaven Formation (sensu King 1981) at Alum Bay, AB 45, contains an assemblage which is indistinguishable from the overlying London Clay Formation.

LONDON CLAY AND BASAL BRACKLESHAM BEDS.

Sections of the London Clay have been examined from the South Lambeth and Leaden Roding Boreholes in the London Basin together with two samples from the base of the unit at Oldhaven Gap. A more complete sequence through the London Clay into the basal Bracklesham Beds was studied at Alum Bay, Isle of Wight.

There has been controversy over the position of the top of the London Clay at Alum Bay, Isle of Wight. Prestwich (1846) placed it at the top of his Bed 6 (see Fig.2.11), White (1921) placed it considerably higher, at the top of Prestwich's Bed 13 while more recently, Eaton (1976) and King (1981) have placed the junction at the top of Prestwich's Bed 7. The London Clay and Bracklesham Beds are therefore discussed below as one unit which contains two distinct microfloral associations.

The microfloral change takes place within Division C-D (King 1981, see Fig.2.11 herein) with assemblages in samples AB 56 to AB 47 belonging to the Classopollis torosus (reworked) Association typical of the London Clay in the London Basin (sections at Leaden Roding and South Lambeth) and samples AB 58 to AB 64 belonging to the Dicolpopollis/Spinizonocolpites spp. Association.

(vi) London Clay: Classopollis torosus (reworked) Association (C(R)).

This association lacks diversity. It is dominated by common to abundant bisaccate pollen and Inaperturopollenites hiatus with higher percentages of Tricolporopollenites cingulum (generally common to very common) than in any other microfloral association. Trilete spores and monocolpate pollen are also common while small tricolpate pollen are rarer than in other marine deposits (e.g. Thanet Beds). However, the most significant elements are Classopollis torosus (common to very common), which is considered to be reworked, and the associated common/very common Spheripollenites spp. and ?Perinopollenites elatoides. It is probable that these too are reworked although it is difficult to prove this. Other reworked species which occur in the London Clay include the Carboniferous genus Lycospora, Rhaetic species Riccisporites tuberculatus and Rhaetipollis germanicus as well as longer-ranging Mesozoic species Vitreisporites pallidus, Cerebropollenites mesozoicus, Callialasporites dampieri and Chasmatosporites spp. (Appendix 2).

Assemblages from the base of the London Clay at Oldhaven Gap (OG 25, OG 26) are different, Classopollis torosus, Spheripollenites spp. and ?Perinopollenites elatoides are rare, as is Tricolporopollenites cingulum. Tricolpate pollen is more common than at other localities. However, the fairly common/common Platycaryapollenites platycaryoides at Oldhaven Gap does correspond to the more common occurrence of this species at the base of the London Clay in the South Lambeth and Leaden Roding Boreholes.

Microplankton in this association are comparatively diverse but no attempt was made to identify all species present, "other dinoflagellate cysts" are therefore well represented in Figs. 5.12, 5.15 and 5.16. Chorate cysts (undifferentiated) are also common. The rare occurrence of Dracodinium solidum in Division B2 at Alum Bay, AB 52 and AB 54, confirms the presence of the Dracodinium solidum Zone of Costa & Downie (1976, 1979).

(vii) London Clay to basal Bracklesham Beds: Dicolpopollis spp./Spinizonicolpites spp. Association (D/S).

This microfloral association is present only at Alum Bay, in samples AB 58 to AB 64. It is distinguished by a marked decline in the species so characteristic of Association C(R), Classopollis torosus, Spheripollenites spp. and ?Perinopollenites elatoides and in bisaccate and inaperturate pollen (although the latter still remains common).

The association is diverse and is characterised by several significant species which occur more commonly here than in the underlying unit. These include tricolpate pollen, Monocolpopollenites tranquillus, Dicolpopollis spp., Nudopollis spp. and Plicapollis pseudoexcelsus. Also characteristic are rare species which nonetheless occur consistently, Spinizonocolpites spp., Tricolporopollenites iliacus, T. margaritatus, Restoniidites spp., Pompeckjoidaepollenites subhercynicus (8% at AB 63) and Interpollis spp. Finally there are several rare species which first appear (stratigraphically) here. Although they only occur

sporadically they form an important element in this microfloral association; Diporites iskaszentgyorgyi, Thomsonipollis magnificus, T. magnificoides, Brosipollis striatobossus, Anacolosidites pseudoefflatus and Tricolporopollenites sp. A (= "T. srivastavai" Gr.-Cav. unpublished 1977).

The highest samples examined, AB 63 and AB 64, contain very rare algae, only acritarchs, leiospheres and Ovoidites ligneolus. Acritarchs are also generally abundant in the remaining samples, AB 58 to AB 60, with Ovoidites ligneolus and Schizosporis sp. at AB 57 and AB 60. However, the most characteristic feature of the microplankton in the lower part of this association is the presence of Areoligera/Glaphrocysta spp. (abundant at AB 57) and of Apectodinium spp. at AB 57.

Bracklesham Beds.

Samples AB 68 and AB 70 come from higher in the Bracklesham Beds and no separate microfloral associations have been distinguished. Significant species from these samples are considered below, in section 5.3.

5.2 FACTORS INFLUENCING THE DISTRIBUTION OF PALYNOMORPHS IN SEDIMENTS

(i) Relationships between miospore assemblages, plant communities and depositional environments.

Any fossil miospore assemblage recovered from a sediment is only a small part of the total microflora which was originally produced. During transport and burial a variety of factors will act upon the assemblage to deplete it and to change the relative proportions of its various constituents.

The diversity of the original pollen rain is determined by the composition of the "parent" plant community, but it is debatable whether the pollen rain can ever reflect the true proportions of individual species within that community since the amount of pollen produced by different species is very variable. In general wind

pollinated species produce large quantities of pollen and are often over-represented in the microflora while insect pollinated species produce small quantities of pollen and are consequently under-represented (Whitehead 1969, Proctor & Yeo 1973).

Nevertheless it is often possible to recognise microfloras of local origin. Coals, particularly if they are associated with rootlet beds or seat-earths,are usually interpreted as swamp deposits (Cohen & Spackman 1977). Similarly lignites represent local plant accumulations or swamps within a variety of depositional environments, including fluvial, deltaic or lagoonal (Nichols & Traverse 1971). Some lake and lagoonal sediments may also contain spores/pollen produced by the local vegetation (Tauber 1967).

Comparatively few microfloras are of local origin however, the vast majority have undergone some transportation. Some miospores are trapped and decay amongst the vegetation and never enter the drainage system or air stream, others are destroyed during transportation. Wind-borne pollen may be carried long distances, Erdtman (1943) notes long-distance transport of pollen across the North Atlantic and the pollen of Pinus and Picea forms up to 20% of total pollen in samples from the Canadian arctic, 400km north of the forest (Lichti-Federovich & Richie 1968, Collinson 1978). Part of a water-borne assemblage may be deposited within the drainage system, on levees, on the flood plain or within distributary channels, before it reaches the main basin of deposition.

Once in the marine environment the miospores behave as sedimentary particles. Sorting and winnowing occur, the larger, heavier types are deposited near shore while the smaller or lighter elements remain in suspension and are carried off-shore where their ultimate distribution may be determined by currents (Muller 1959, Cross et al. 1966, Tschudy 1969). Cross et al. (1966) show that nearshore areas with coarse sediments have lower pollen concentrations than areas slightly further off-shore with finer-grained sediments. Some of the very highest absolute frequencies of pollen in the Gulf of California occur in silty sediments,

either silty-clay or clayey-silt, with 42,000-65,000 grains/g of bottom sediment in water of 30-250 fathoms. The greatest diversity also occurs in these areas slightly off-shore, particularly near the mouths of rivers while diversity and absolute numbers of pollen and spores decline further off-shore (Muller 1959, Cross et al. 1966).

From these general principles it is possible to recognise local and regional elements within the early Tertiary microfloras from southern England and to distinguish depositional sites which are local, intermediate or distant in terms of proximity to parent vegetation (section 5.3).

It is more difficult to make assumptions about the habitat of the plants which produced the fossil microflora. Although some Tertiary pollen is very similar in morphology to that of a particular extant genus, and in such cases it may be possible to accept affinity between them, the living members of the genus may occupy a variety of habitats. For example, different species of Taxodium live in lowland swamps (T. distichum) and in upland forests (T. ascendens, Braun, 1964), some species of Restio and Centrolepis inhabit dry regions but others grow in swamps (Machin 1971).

One group of plants in which it is possible to assume that the habitat of the fossil was similar to that of the recent relative is the group of aquatics, including the Typhaceae/Sparganiaceae and Salviniaceae. The same appears to be true for the palms, for Nipa and for Sarcococca and Pachysandra (Grey & Sohma 1964, Machin 1971, Collinson 1978). Machin (1971) makes various palaeocological interpretation of Tertiary microfloras based on the assumption that the "habitat requirements of the recent genera identified as microfossils have not appreciably altered during their recognisable history".

There must be cases, however, where a genus has changed its ecological requirements during a long geological history. Certain taxa are much more restricted in their present geographical distribution than during the Tertiary. The Restoniaceae and Centrolepidaceae are now restricted to the southern hemisphere (Ladd 1977), Reevsia Lindl. is endemic

in south-east Asia (Petrov & Drazheva-Stamatova 1972) and some of the Juglandaceae, Engelhardtia, Platycarya and Pterocarya, are now restriced to the Old World although they are present in Tertiary pollen floras in North America (Stone & Broome 1975). The presence of abundant Platycarya-type pollen, of local origin, in the early Tertiary lignite at Shorne Wood, Kent, in a lowland, probably coastal environment, suggests a change in habitat for this genus (see Section 5.3 below).

One can only speculate on the distribution of plants belonging to extinct groups such as the Normapolles or the primitive Juglandaceae by the association of their pollen with types of "known" affinity.

In sediments older than the Tertiary interpretations become even more speculative. In spite of the limitations several authors have interpreted miospore assemblages in terms of the distribution and ecological requirements of different members of the plant community (Neves 1958, Chaloner 1958, Smith 1962, Habib 1966, Hughes & Moody Stuart 1967, Machin 1971, Batten 1975, 1977). Others have discussed the relationships between fossil miospore assemblages and different sedimentary environments (Neves 1958, Muir 1964, Hopping 1967, Nichols & Traverse 1971, Batten 1973).

(ii) Factors which influence the distribution of dinoflagellate cysts in sediments

Although many studies have been undertaken of the distribution of the motile stage of living dinoflagellates (see discussion in Lentin & Williams 1980) comparatively little is known about the occurrence of dinoflagellate cysts. The most comprehensive work to date is that of Wall et al.(1977) who examine the distribution of cysts in the water column and the underlying sediments from estuarine, continental shelf, slope and rise zones and abyssal plains from the North and South Atlantic Oceans between 62°N and 27°S, including the Caribbean and Mediterranean Seas. Their work shows that cyst distribution is influenced by two major trends, firstly an inshore-off-

shore trend and secondly, a longitudinal or climatic trend. They recognise four marine environments, estuarine, neritic (coastal), transitional neritic-oceanic and oceanic (pelagic) defined on both watermass (in which the cysts are produced) and on the topographic zone beneath it (in which the cysts are ultimately buried). Different species are seen to attain their peak abundances in either estuarine, shelf, slope-rise or abyssal zone sediments while a few species are limited in distribution to off-shore sediments and do not occur inshore of the continental shelf. Taking latitudinal differences into account the authors distinguish those species which are restricted to particular environments or have their peak occurrence there. These include estuarine species restricted to temperate or tropical-subtropical areas, or cosmopolitan estuarine species which are not climatically restricted; neritic species and neritic oceanic species which are mainly cosmopolitan; and oceanic species which only occur in tropical-subtropical areas. In more temperate areas the cysts which occur in the oceanic environment are also found in shelf sediments. As well as distributions of individual species distinct cyst associations are defined which occur in similar environments, related primarily to climate and proximity to shore.

In general species diversity tends to increase seawards, partly because of mixing with more oceanic species but also because many species which occur in the slope-rise zone sediments are probably not recent in age or are allochthonous estuarine-neritic modern specimens. Cyst densities per gram of sediment also tend to increase off-shore but mainly because of sedimentological factors.

Certain species are even more specialised and do not occur in areas where there are fluctuations in salinity or in high energy environments where strong currents and turbulence occur. Thus they are restricted to more stable marine environments such as small bays and inshore areas in cool temperate and tropical-subtropical latitudes and to pelagic subsystems in tropical and warm-termperature latitudes. The recognition of such restricted types in fossil assemblages should be extremely useful for palaeo-

ecological and palaeoenvironmental interpretations.

The authors conclude that, although there is a large oceanic component amongst dinoflagellates as a whole, the production of "fossilizable" cysts by living dinoflagellates is an adaptation of life in the unstable-unpredictable hydrographic regimes which are typical of shallower-water environments along continental margins and around oceanic islands (Wall et al. 1977).

Within the early Tertiary of southern England Downie et al. (1971) recognise a series of dinoflagellate cyst associations based on the relative proportions of morphologically similar cyst groups and relate these to open marine and brackish environments. They suggest that the sequence of associations may be used to define transgressive/regressive cycles in the early Tertiary. Denison (1977) discusses fossil dinoflagellate cyst associations from the early Tertiary of southern England in relation to nutrient supply, variations in salinity, proximity to shore and energy of environment (see section 5.3 below).

5.3 DISTRIBUTION PATTERNS OF SELECTED SPECIES: DISCUSSION AND INTERPRETATION.

The microfloral associations defined above (section 5.1) can be interpreted both in terms of environment of deposition and site of spore/pollen production. Certain associations occur in local deposits; others are "distant" in that most of the spores and pollen they contain appear to have been transported considerable distances before deposition; and for other associations the depositional site is "intermediate", between the local and distant environments; they contain a mixture of palynomorphs of comparatively local origin together with others from further afield. The acid resistant microplankton present in each association give valuable information about the environment of deposition.

Individual spore/pollen species show variations in their distribution pattern which suggests that at some localities they are of local origin while at others they form part of the regional, transported element.

In most associations there is a background microflora

of common small tricolpate and tricolporate pollen together with species which occur sporadically throughout the early Tertiary sequences,but usually in comparatively low percentages. These are considered to come from a widespread regional flora with the plants that produced them only rarely (if ever) growing adjacent to the site of deposition. They include species of Alnipollenites, Ulmipollenites, Caryapollenites, Intratriporopollenites, Compositoipollenites, Subtriporopollenites and the Momipites group, with Triporopollenites robustus, T. plektosus and Subtriporopollenites intrastructurus.

1. LOCAL SITES OF DEPOSITION.

(i) Woolwich facies; Lignite.

Assemblages of local origin and deposition are present in the lignites in the Woolwich facies of the Woolwich and Reading Beds at Shorne Wood, Kent. The features which distinguish this as a local assemblage are firstly abundance; several species occur here more abundantly than at any other locality (e.g. Sparganiaceaepollenites spp., Pistillipollenites mcgregorii), and some rare species occur more consistently here; secondly, several species occur in clusters, sometimes large enough to suggest that they may be from whole anthers (e.g. Platycaryapollenites platycaryoides); thirdly, the presence of megaspores (e.g. of the Salviniaceae, Martin 1976) and of seeds (of Typhaceae-type); and finally, the sediment itself, a relatively thick, in situ lignite.

The following local elements occur:

Platycaryapollenites platycaryoides.

This species has its maximum occurrence (62.4%) in the lignite sample JL 865 which also contains large clusters of pollen (pl.12, fig.1), possibly whole anthers. This distribution suggests that the trees were growing more or less at the site of deposition, dropping pollen and anthers directly into the swamp below. The species remains common throughout the lignite although at the top of the sequence,

JL 866 and JL 867, its apparent decline (to 16% and 10% respectively) is a response to the over representation of Sparganiaceaepollenites spp.

Sparganiaceaepollenites spp.

The genus is very common to abundant in JL 867 and JL 866 (25% and 33% respectively) and probably indicates in situ deposition within a reed bed. Further evidence for the very local origin of the microflora is the presence of fairly common Typha-type seeds in the same two samples (see pl.17).

Normapolles; undifferentiated Plicapollis pseudoexcelsus and Nudopollis terminalis and N. endangulatus.

This group is more common in the lignite than at most other localities (but see also the Bracklesham Beds at Alum Bay), and reaches its maximum in the same two samples as Sparganiaceaepollenites spp. Perhaps this indicates a habitat adjacent to the reed bed for the plants which produced Normapolles-type pollen. Martin (1976) suggests that they may have been part of the riparian forest.

Salviniaceae.

Comparatively rare microspore massulae of Salvinia-type (=Salvinia cobhamii Martin 1976) occur in the sample JL 865 although no megaspores, nor dispersed microspores, were observed. Martin (1976) records megaspore and microspore massulae of both Salvinia and Azolla in the lignite at Shorne Wood, but only in his basal sample, R1434 (see discussion below).

Pistillipollenites mcgregorii.

Although never abundant this species occurs most consistently in the lignites and has its maximum, 5%,. in sample JL 865. Occasional clusters of a few grains also occur at this level. Martin (1976) records over 10% of P. mcgregorii in sample R1434, in association with Salviniaceae. This leads him to suggest that Pistillipollenites also may have been produced by either a waterside or even an

aquatic plant. It may be significant that its peak in sample JL 865 also coincides with my only record of Salviniaceae.

Rouse & Srivastava (1970) review the distribution of P. mcgregorii in the late Cretaceous and early Tertiary of North America and, from the pollen morphology and its frequent occurrence in clumps, they suggest that P. mcgregorii was probably entomophilous, or was produced in clusters inside relatively closed flowers. They take these characters, and its distribution in relatively fine-grained sediments in fairly narrow stratigraphic zones, to indicate deposition close to source rather than after long-distance transport by water or wind. Nichols & Traverse (1971) also favour a local (indigenous) origin for this species in the lignites in the Wilcox Group in East Texas. They suggest that the plants producing this, and other indigenous pollen types, lived in coal-forming swamps within a fluvial environment (the Mount Pleasant Fluvial System).

Laevigatosporites haardti and L. discordatus.

These species are never abundant but occur fairly commonly in the lignite, and probably come from members of the local fern flora.

Smooth trilete spores.

Large fern spores, of Leiotriletes-type, occur consistently through the lignite. Although they only show as rare in the counts they are a conspicuous element on the slides (possibly because of their large size) and like the Laevigatosporites spp., are considered to be of local origin.

Palmae.

Monocolpopollenites tranquillus is generally more common here than elsewhere. Machin (1971) records similar palm pollen (Thrinax, pl.2, fig.11) associated with aquatic plants but points out that a few accounts of the present-day ecology of Thrinax describe it as a plant of shore-lines or of drier ridges within swamp (1971, p.856).

Tricolpites sp. A.

This species is of unknown affinity. It is very common in JL 864 where several large clusters were recorded but is only sporadic elsewhere, even within the lignite. One possible explanation of this limited distribution is that the plant was normally a comparatively rare (? or scattered) forest element so that an occurrence at the edge of the site of deposition was purely accidental.

Zygnemataceae-types.

The lignite samples all contain rare specimens of one or more algal species which are probably attributable to the Zygnemataceae; Ovoidites, Schizosporis, Tetraporina and Indeterminate Type 1. Van Geel & Van der Hammem (1978) describe spores (zygospores and/or aplanospores) of Spirogyra and Mougeotia which are morphologically similar to Ovoidites/Schizosporis and Tetraporina respectively. They point out that, although comparatively little is known about the ecology of various species, many forms seem to prefer relatively extreme conditions such as temporarily standing water or strong daily fluctuations in pH or temperature. Although they are usually found in fresh water, some species occur in brackish environments and are often present in small lakes and pools or in the littoral zone of larger lakes. They conclude that the presence of zygospores and/or aplanospores of Zygnemataceae is indicative of stagnant, shallow fresh-water habitats. The occurrence of these forms in the Woolwich facies lignite sequence therefore indicates the occasional presence, even if only temporary, of a certain amount of open water.

A comparison of the microfloras from two sites within the lignite reveals lateral differences in floral distribution (site R; Martin 1976, samples R1434-R1439 and site JL; samples JL 864-JL867 herein).

For Martin (1976, p.183) the section records the shallowing of a lake by the encroachment of reeds and then a possible reflooding. He suggests that the Juglandaceae, and perhaps the plants which produced the Normapolles pollen, formed riparian forest which advanced and was consequently

over represented during the drying phase, while the Cupuliferae (Tricolpopollenites liblarensis and related species) were a more long-distance component (1976, p.183).

The various stages of this sequence, open water, development of reed beds, advance of the forest, can be distinguished at both sites but they occur in a different order and are not equally well developed.

The open water phase is best represented by sample R1434 which contains Salviniaceae and about 30% of small tricolpate pollen of the Tricolpopollenites liblarensis group (probably with affinity to Cupuliferae). Perhaps this was near the centre of the lake since the abundance of the more regional pollen, and relative scarcity of local elements, suggests there was a considerable break in the forest cover. In contrast, there is little evidence for open water conditions at site JL until sample JL 865 which does contain rare Salviniaceae but is dominated by Platycaryapollenites platycaryoides (62.4%), including many pollen clusters. This is much more indicative of deposition at the very edge of the lake with pollen from the forest vegatation which surrounded the open water dominating the assemblage and masking spores from the aquatic plants as well as any regional elements which might be present.

The period of open water at site JL appears to have been followed by infilling and the encroachment of reeds since samples JL 866 and JL 867 are dominated by Sparganiaceaepollenites spp. (25%-33%) and also contain Typha-type seeds, with only 10%-16% of P. platycaryoides. The single productive sample from the north side of the carriage-way, JL 879, with an assemblage of Sparganiaceaepollenites spp., 13.6%; P. platycaryoides 36.8% and Normapolles, 9.2%, also represents the reed bed phase.

There is no comparable abundance of Sparganiaceaepollenites spp. at site R, where it forms only about 3% in samples R1435 and R1436 and is accompanied by 30%-50% P. platycaryoides with Normapolles and Gallopollis minimus (possibly one of the forest elements). In the highest sample, R1439, c.3% Sparganiaceaepollenites spp. occur with only 15% P. platycaryoides while there are increases in G.

minimus, Normapolles and the T. liblarensis group. Although Martin uses the presence of Sparganiaceaepollenites spp. to suggest this as a period of reed encroachment these mixed assemblages seem more indicative of deposition at a site at the edge of the reed bed which received pollen from both the forest and reed communities.

The lignite therefore represents a period of emergence after the deposition of the marine Woolwich Bottom Bed and prior to submergence during the deposition of the Woolwich Shell Beds. As shown in Chapter 2,lignites occur at this horizon at several localities, some with associated rootlet beds, e.g. in the temporary exposures along the M25 motorway, at Aveley (G. Ward, personal communication). The lignite at Swanscombe appears to have undergone minor transport or redeposition since it occurs as clasts within bioturbated clays and sands. The lignite is most similar in lithology to those from the north side of the carriage-way at Shorne Wood, which were generally barren of palynomorphs. In the Swanscombe sample the microflora is very sparse and contains marine microplankton (Apectodinium spp.). It probably comes from the associated clays rather than the lignite itself. C. King (personal communication) suggests that the lignite may have been in situ relatively close to its present position but was eroded and redeposited during the subsequent transgression. Elsewhere in the central and eastern part of the London Basin there is also evidence of emergence at a comparable level. In the Intermediate facies of the Woolwich and Reading Beds and also further east (e.g. at Charlton) the marine sands of the Bottom Bed are overlain by fluvial mottled clays. Towards the top, this fluvial unit locally contains calcareous nodules, possibly caliche deposits (e.g. the Concretion Bed of Rundle 1972, present in some parts of the exposure at Charlton, north west of the section I collected), and sun cracks. At Upnor, Kent, purple sandstones at the top of the Bottom Bed are interpreted as soil horizons while further west, silicified sandstones and ferruginous staining are believed to be related to soil-forming processes (Berry; C. King; personal communication).

(ii) Reading facies of the Woolwich and Reading Beds.

Samples examined from the western end of the London Basin generally come from the lower part of the unit, below the mottled clays. The base of the sequence is represented in the M4 motorway section, north of Hewins Wood and samples contain marine microplankton (see below) but very few spores and pollen. At Pincents Kiln the section also immediately overlies the Chalk but the basal samples contained such sparse microfloras that no quantitative data were collected. The silty clays which form most of the exposure contain numberous fragmentary leaves and leaf impressions and contain rich spore/pollen assemblages with rare dinoflagellate cysts and acritarchs, suggesting some brackish to marine influence during deposition. This section could perhaps be considered as intermediate in terms of depositional site, however the microfloral assemblages are very similar to those recovered from the two samples from Cold Ash Quarry, from a lense of silty clay which occurs within massive cross-bedded sands underlying the mottled clay. The sedimentological evidence suggests that the clay lenses were deposited as isolated pockets within a braided river system and the associated macroflora also points to a local source. The single samples from Waterloo Kiln and Knowl Hill are from the same part of the sequence, below the mottled clay, and contain similar microfloras, all part of the Microfloral Association M/I. The distribution patterns of selected species in the western part of the London Basin are therefore considered together below.

(a) Local elements within the microflora.

Triatriopollenites confusus.

This species is common in the two samples from Cold Ash Quarry (NB 1, 8.4%; NB 2, 13.2%), very common towards the top of the section at Pincents Kiln (PK 34, 23.6%) and rare to fairly common, less than 4%, through the rest of the section. Even so, it is more persistent in this area than in the Woolwich facies or at any other section examined and is characteristic of the M/I Microfloral Association.

The comparative abundance of the species at Cold Ash Quarry perhaps indicates local origin there. Crane

illustrates pollen of this type which he found adhering to the perigone surface of the nutlet Palaeocarpinus laciniata (1981, Fig.38,39). He assigns this fossil to the tribe Coryleae of the Betulaceae but points out that it exhibits the nutlet characters of Carpinus but the bract arrangement of Corylus. He considers the pollen that he illustrates to be similar to Carpinus triangularis (sic.) Stanley (1965) (= Triatriopollenites subtriangulus herein) and compares it with a scanning electron micrograph of extant Corylus avellana (Fig.37). I think that the fossil specimens illustrated are closer to Triatriopollenites confusus. Crane points out that, although the illustrated form is the most abundant, several of his perigone cuticle preparations have a variety of pollen grains adhering to the outer surface. (These do include grains of Triatriopollenites subtriangulus, personal observation). He concludes that the evidence is insufficient to indicate that the pollen he illustrates is in anyway botanically associated with the fruits. The issue is further complicated by the existence of pollen specimens which seem to be transitional between T. confusus and T. subtriangulus (plate 14, fig.7,9).

Momipites/Triatriopollenites spp. group.

The primitive Juglandaceae appear to show greater diversity in these localities than further east. There is no dominance of Platycaryapollenites platycaryoides as occurs in the P/S and P/A/T Microfloral Associations from the Woolwich lignite and Woolwich Shell Beds, the species forms only c.3% of assemblages, compared to its common-abundant occurrences in the Woolwich facies. In contrast, Maceopolipollenites rotundus and Triatriopollenites subtriangulus occur more consistently in the Pincents Kiln and Cold Ash Quarry sections and undifferentiated species of the Momipites/Triatriopollenites group are generally more common here.

Intratriporopollenites spp.

This genus occurs throughout the London Basin and also at Alum Bay but is usually sporadic. It is consistently present through the Pincents Kiln section, generally at 5% or less, and is slightly more common at Cold Ash Quarry and

Waterloo Kiln. This is a characteristic element of the M/I Association.

Compositoipollenites spp.

The peak occurrence of Compositoipollenites spp. occurs at Cold Ash Quarry; 11.2% in NB 2 where there are also some small clusters (plate 10, fig.9). Crane (personal communication) reports the genus as very common in his site C at this locality. It remains fairly common in sample NB 1 (2.4%) and at Waterloo Kiln (4.2%) and occurs consistently at Pincents Kiln with its maximum occurrence of 4% in PK 20. Although it is never abundant the genus is a very characteristic element of the M/I Association. It does occur elsewhere in the London Basin and at Alum Bay but is sporadic. Its more persistent occurrence at Pincents Kiln suggests it was of comparatively local origin and had not been transported far while at Cold Ash Quarry it is probably of local origin.

The pollen morphology suggests affinity with the Icacinaceae, particularly Iodes (Krutzsch 1961, Sein 1961) a tropical to subtropical genus (Machin 1971).

Tetracolporopollenites spp.

Pollen of this type has been referred to the Sapotaceae, evergreen trees chatacteristic of the tropical and lowland rain forest, but also found in the shoreline vegetation of the south Florida Keys (Machin 1971).

This form is most common at Cold Ash Quarry (5.2% in NB 1) and occurs consistently at other sections in the area, but normally at less than 2%. The only other microfloral association where it is as persistent is the D/S Association at Alum Bay, in the upper London Clay to basal Bracklesham Beds.

Inaperturopollenites hiatus and I. polyformosus.

Inaperturopollenites hiatus has a variable distribution in this area, it is least common at Cold Ash Quarry (4.8%, NB 2), forms about 11% of the microflora at the base of the Pincents Kiln Section 1 and has peaks of 30.8% (PK 23); 25.2% (PK 4); 23.2% (PK 29) and 19.2% (WK). The distribution of the species throughout the London Basin is also variable, in general it is common to abundant in the marine deposits but can also be common in "intermediate" depositional areas

(e.g. Woolwich facies, Woolwich Shell Beds).

Inaperturopollenites polyformosus is generally rare, present mainly in the upper part of Pincents Kiln Section 1 and in Section A and having irregular distribution through the rest of the London Basin and at Alum Bay (Appendix 2).

Pollen of I. hiatus type is generally considered to have affinity with the Taxodiaceae. Simpson illustrates similar forms under the names Taxodium and Cunninghamia (1961, pl.1, fig.8 and pl.2, fig.3, Taxodium distichiforme Simp., comparable to extant T. distichum Rich., pl.1, fig.8a,9a; Cunninghamia rugosa Simp., pl.1, fig.10, comparable to extant C. lanceolata Lamb., pl.1, fig.10a). Gruas-Cavagnetto (1977, p.41) suggests affinity with Taxodium and possibly Glyptostrobus and Cunninghamia.

Inaperturopollenites polyformosus is distinguished from I. hiatus by the presence of a distinct papilla but a small papilla is visible in some specimens of I. hiatus and is certainly present in the recent Taxodium pollen examined by Simpson (1961, p.429 and pl.1, fig.9a) and in fossil specimens referred to cf. Glyptostrobus by Machin (1971, pl.1, fig.10).

Fowler et al. (1973) suggest that dispersed taxodiaceous pollen which gape open, or in which the papillae cannot generally be seen (i.e. I. hiatus type) is likely to belong to the Taxodium morphological group. The distinction between the two species is not entirely clear therefore. I have only included specimens with a definite papilla in I. polyformosus (e.g. plate 2, fig.13,14 herein).

Gruas-Cavagnetto (1977) suggests I. polyformosus is related to extant Sequoia, Metasequoia and Cryptomeria although affinity with Glyptostrobus is also a possibility (Machin 1971).

Today Taxodium is an important element within river swamps of Florida (Machin 1971, Gruas-Cavagnetto 1977) but also lives in upland forest (Braun 1964). Glyptostrobus is endemic to forests in southern China, between 22^{o}-26^{o}N, in low lying areas and coastal swamps while Cunninghamia also occurs in China as an important element in forests in mountains but has an altitudinal range from sea level to 2,000m (Gruas-Cavagnetto 1977).

It is most probable that pollen of this broad morphological type, I. hiatus-I.polyformosus, was produced by more than one genus and that the parent plants occupied habitats as varied as the modern Taxodiaceae. This, in part, would explain the very variable distribution pattern of I. hiatus in the early Tertiary deposits, with pollen coming from a local flora at certain localities (e.g. perhaps Pincents Kiln) and from a mixture of local and more distant (perhaps higher altitude) species into the marine deposits.

Bisaccate pollen.

Different genera have not been distinguished but some of the pollen probably has affinity with Pinus. According to Fowler et al. (1973) the presence of Pinus need not suggest remote source areas of drier upland communities since modern pine species can grow at low altitude in subtropical climates. Today the genus grows in lowland, wet habitats in Florida, often occupying only slightly elevated, though poorly drained areas, within or on the landward side of swamps.

Bisaccate pollen forms about 5% of the microflora in the Pincents Kiln sections, slightly less at Cold Ash Quarry, and may be of comparatively local origin in these deposits.

Tricolpate/tricolporate pollen.

Tricolporate pollen is generally more diverse in the M/I Association than elsewhere in the London Basin. Small tricolpate pollen of the liblarensis/microhenrici and variabilis/parvus groups are relatively common but the majority of tricolpate and tricolporate pollen species are rare. Although there are only a few specimens on each slide these rarer species occur consistently, sometimes as small clusters, and form conspicuous elements in the microflora. The most significant species are listed below.

Tricolporopollenites mansfeldensis.

This species appears to have been of local origin at Site A at Cold Ash Quarry since it forms 16.4% of the microflora in sample NB 1, including several clusters of grains, and in another sample from the same lens , Collinson records as much as 30% (1978, as T. milionii). There is evidence of lateral changes in the microflora within this lense, since

at NB 1 T. mansfeldensis is very rare. It is only sporadic in other sections in this area, less than 1% in Sections 1 and A at Pincents Kiln. Under these circumstances the abundances at Cold Ash Quarry suggest a local source for this pollen.

Nyssapollenites sp. A and Nyssapollenites sp. B.

Although recorded at 1.2% or less in the counts several specimens of both species occur in each slide in samples from Section 1 at Pincents Kiln. Nyssapollenites sp. A also occurs in clusters in sample PK 4 (plate 4, fig.9,10) and appears to be of local origin there. It has not been recognised at Cold Ash Quarry or Knowl Hill but is present in the sample from Waterloo Kiln and rare specimens are present in the Woolwich Shell Beds at Swanscombe and Shorne Wood.

Nyssapollenites sp. B. has only been recorded from Section 1 at Pincents Kiln.

Rhoipites sp. A.

This species is mainly restricted to the Pincents Kiln sections, it occurs as clusters in PK 21 (plate 4, fig.22) and is fairly common (3.6%) in PK 4 and PK 23 (2%). Several specimens were also recorded in sample PK 6 (Section A) which was not counted. Rhoipites sp. A. is present at Knowl Hill but not at Cold Ash Quarry nor Waterloo Kiln.

Other tricolpate, tricolporate species.

Species which are generally rare and very localised or sporadic in distribution include Tricolpites sp. C. (occasionally as small clusters, e.g. at PK 21); Rhiopites sp. B. (NB 1, 4%; PK 21, 1.2%); Tricolpites sp. B. and specimens transitional to Favitricolporites baculoferus (particularly NB 1, NB 2 and WK); F. baculoferus; ?Spinulaepollis sp. (only in samples WK and KH) and undifferentiated "brevicolpate" pollen including ?Cyrillaceaepollenites spp. (pl.7, fig.14-16), mainly at Cold Ash Quarry and Waterloo Kiln. Although rare and of unknown affinity, the presence of these species emphasises the diversity of the surrounding vegetation.

(b) Regional elements within the microflora.

Reworking.

One of the most distinctive Mesozoic pollen types which

frequently occurs reworked in the Tertiary is Classopollis torosus (Pflug 1953, Elsik 1968, Nichols & Traverse 1971, Frederiksen 1980). This pollen occurs sporadically in the Pincents Kiln sections, at about 2% and is also present at Cold Ash Quarry.

Very rare Carboniferous spores are present, Lycospora sp. (in NB 1, PK 20 and PK 4) and Triquitrites sp. (PK 23), with the late Triassic species Ovalipollis ovalis at PK 21 and PK 24 and occasional specimens of the Mesozoic species Vitreisporites pallidus, Chasmatosporites spp., Cerebropollenites mesozoicus and Callialasporites dampieri in the Pincents Kiln sections. Their presence indicates that material derived from the erosion of older deposits, somewhere within the drainage system, was transported into the pools or creeks where Tertiary sediments were accumulating.

Microplankton.

Denison (1977) records "Cyclonephelium conopium" (unpublished species) from the base of the Reading Beds at Pincents Kiln but I have only recovered very sparse microfloras, with rare acritarchs, from comparable levels.

Through the rest of the sequence at Pincents Kiln microplankton are rare (see actual numbers of total microplankton in Appendix 2) and are mainly acritarchs. Rare dinoflagellate cysts occur in PK 4, PK 23, PK 24 and include undifferentiated Areoligera/Glaphrocysta species, chorate cysts and Spiniferites spp. Crane (personal communication) has one or two specimens of Spiniferites sp. from Cold Ash Quarry but considers that they are most probably reworked since Classopollis torosus is present in the same samples and the sedimentological and macrofloral evidence suggest the deposit was formed within a braided river system without direct connection with the sea.

Samples from the M4 Motorway section, north of Hewins Wood, also contain microplankton (Appendix 2). They are most common in the basal sample M4/7(1) (from the Ostrea bellovacina Bed, Fig.2.10) and M4/7(2) and have moderately diverse assemblages. Dinoflagellate cysts present include Areoligera/Glaphrocysta spp., Cordosphaeridium sp., Homotryblium sp., Achomosphaera ramulifera and undifferentiated

chorate cysts, together with common acritarchs. The sparse microfloras from the remaining samples are dominated by acritarchs.

(iii) Comparison with the macroflora.

Comparative studies of macrofloras and microfloras have shown that they compliment each other; both are needed to describe the total flora (Sein 1961, Machin 1971, Fowler et al. 1973). While the macroflora frequently is biased towards local species which have been deposited where they grew, or to species which live near water and so could be transported easily, the microflora often contains many spores and pollen transported by wind or water from entirely different communities. A combination of microfloral and macrofloral evidence will therefore give a broader picture of the vegetation as a whole. It may be difficult, however, to relate the fossils to present day plant communities.

Although rich and diverse microfloral assemblages occur in samples from Crane's Site A at Cold Ash Quarry and from Pincents Kiln, comparatively few species have a morphology which is sufficiently distinct to allow them to be referred to extant genera or even families. Those which can be recognised at family level include Milfordia incerta, Restoniidites minimus and R. hungaricus (Restionaceae, Centrolepidaceae), Inaperturopollenites hiatus, I. polyformosus, and I. dubius (included in Inaperturopollenites spp.) (Taxodiaceae) and Maceopolipollenites rotundus, Momipites spp. (Juglandaceae). Only the following types recorded from these sections have definite morphological similarity with a single extant genus; Intratriporopollenites (Tilia), Nyssapollenites (Nyssa), Caryapollenites (Carya), Compositiopollenites rhizophorus (Iodes), Pandaniidites texus (Pandanus), Platycaryapollenites platycaryoides (Platycarya), Alnipollenites verus (Alnus), Reevsiapollenites (Reevsia) and Tricolporopollenites iliacus (Ilex). Nevertheless it is by no means certain that the plants which produced these pollen were identical with the modern genera.

Similarly, some of the macrofossils have no exact modern equivalent. From Cold Ash Quarry, Crane describes (1981) bracts and fruits of Palaeocarpinus lacinata which, although

referable to the tribe Coryleae of the Betulaceae, exhibit a combination of characters which does not occur in any extant genus. He concludes that, although the fossil is most similar to Carpinus the bract arrangement would probably be regarded as sufficient justification for a new genus in the taxonomy of extant Betulaceae. These fossils are closely associated with the leaves Craspedodendromophyllum acutum Crane which also show a combination of features not exhibited by any modern genus. Although leaves of this general morphological type have previously been attributed to the Betulaceae, Crane notes that several other families have a similar leaf architecture and affinity with them cannot be ruled out entirely. The close association of these leaves and the fruits and bracts of P. laciniata at Sites A and B, and their virtual absence at other sites at Cold Ash Quarry, leads Crane to suggest that they are both parts of the same plant species and that most of fossils were deposited close to where they grew. The associated pollen type is not yet known. Possible candidates are the triatriate pollen Triatriopollenites confusus, T. subtriangulus and forms transitional between them which occur commonly at site A. These have been found adhering to the surface of the nutlet P. laciniata (see discussion under "Triatriopollenites confusus").

The commonest macrofossils in sites A and B are Trochodendroides ("Cercidiphyllum") leaves. These are associated with fruits and seeds which are known to have been borne by the same plant (Crane 1981). It is probable that this also was of local origin, but, as yet, the associated pollen type is unknown.

For most other families present as macrofossils (see Table 3.2) no associated pollen type has yet been recognised in the microflora. An exception is the Ericaceae which are represented by Rhododendron seeds (Collinson & Crane 1978) and by dispersed anthers and seeds, tentatively referred to Vaccinium (Collinson 1978). Although it is present, pollen of Ericaceous affinity (Ericipites spp.) is extremely rare in the area as a whole and is only represented by single specimens in sample NB 1 and NB 2 (Appendix 2).

The leaves Lauraceaephyllum stenolobatus occur at Cold Ash Quarry but are also abundant at Pincents Kiln. One of

their distinctive characteristics is the presence of resin bodies (Crane, personal communication). These survive palynological processing and are present in my palynological preparations from Pincents Kiln. In this situation they provide an oblique piece of evidence for the presence of Lauraceae although dispersed resin bodies, without the macrofossils, would be of little significance. Unfortunately no pollen which could be assigned to the Lauraceae has been identified.

At Cold Ash Quarry several lines of evidence point to a local origin for the macroflora; firstly the macrofossils themselves, particularly the close association of different organs from a single plant, and the concentration of fossils of one family in particular sites and their virtual absence from others; secondly the sedimentological evidence which indicates that the silt and clay pockets were deposited within a braided river system, each isolated from the others. The microflora is comparatively diverse but does contain several species which are more abundant here than at other localities, particularly Tricolporopollenites mansfeldensis, Triatriopollenites confusus, Compositoipollenites rhizophorus, Rhoipites sp. B. and Tetracolporopollenites spp. These may be of local origin. Elements which have probably been transported into the deposit are the rare reworked Classopollis torosus and Spiniferites sp. and possibly some of the more ubiquitous pollen types which may come from a variety of sources, small tricolpate and tricolporate pollen, bisaccate pollen and Inaperturopollenites hiatus. Collinson and Crane (1978) consider it possible that the Rhododendron seeds may have undergone some transport before desposition.

The leaf-bearing horizons at Pincents Kiln are much more continuous than the isolated silt and clay lenses which contain the macrofossils at Cold Ash Quarry. There is no evidence for the presence of an active, high energy river system here, the depositional area appears to have been more coastal (from the presence of rare dinoflagellate cysts and acritarchs), with the leaves being deposited in stagnant pools or sluggish backwaters at the seaward end of a delta. The microflora is generally similar to that at Cold Ash Quarry, although the individual "local" species are not necessarily the same; Nyssapollenites spp.,

Intratriporopollenites spp. Compositoipollenites spp. and at one level, Triatriopollenites confusus. The higher percentages of Taxodiaceous pollen (I. hiatus) and bisaccate pollen, may either be from local or distant sources while the very common small tricolpate pollen (particularly variabilis/parvus group) has probably been transported considerable distances from a variety of sources.

2. DISTANT SITES OF DEPOSITION.

These depostional sites are only "distant" in the sense that the spore/pollen component of the microflora has generally been transported long distances before deposition. They are all marine and consequently contain marine microplankton which are of comparatively local origin and their distribution is controlled by factors such as salinity, proximity to shore, temperature variations, turbulence etc. (see 5.2 above). Variations in the distribution patterns of both groups are considered below.

The distant depositional sites include the marine deposits of the Thanet Beds, Woolwich Bottom Bed and the London Clay which contain Microfloral Associations A/M, A/G+D and C(R). The Oldhaven Beds would also fall into this category but as the microfloras are so sparse they are not considered further (see Appendix 2 for OG 27).

Spores and pollen.

In general, all spore/pollen assemblages from these deposits contain a high proportion of bisaccate pollen, inaperturate pollen and small tricolpate pollen with some small tricolporate pollen and smaller quantities of several stratigraphically long-ranging genera.

The main characteristics of each Microfloral Association are presented in section 5.1 above. The spore/pollen assemblages have much in common. Most of the species recorded are distant elements and occur elsewhere, nearer to source, in the local and intermediate depositional sites. Three groups are recognised;

a) Dominant species; pollen which is produced abundantly, is easily transported by wind or water, appears to survive long-distance transportation and consequently is common to

abundant within the microflora. This includes bisaccate pollen, Inaperturopollenites hiatus and Inaperturopollenites spp. (probably all of Taxodiaceous affinity), small tricolpate pollen of the variabilis/parvus group and (mainly in the London Clay, C(R) Association) Tricolporopollenites cingulum. As shown above the parent plants which produced the bisaccate and inaperturate pollen may have occupied a variety of habitats and probably also had a widespread distribution. The same may have been true for the tricolpate and tricolporate pollen producers. Thus the pollen which accumulated abundantly in the marine environment may have come from a wide area, including coastal lowland and more distant, possibly upland, sites.

b) Rare species; species which are rare to fairly common in this environment but may be common or abundant at local or intermediate depostional sites. These include Platycaryapollenites platycaryoides, Monocolpopollenites spp., Nudopollis spp., Plicapollis pseudoexcelsus, Compositoipollenites spp. and Sparganiaceaepollenites spp. (mainly in the London Clay). The plants which produced this pollen may have been fairly localised in distribution (particularly so for the Sparganiaceaepollenites-plant) and their pollen transported into the marine depositional area. The fairly common occurrence of trilete spores at some localities (Thanet Beds at Pegwell Bay, London Clay at South Lambeth and Alum Bay) is anomalous since such spores are frequently deposited close to river mouths or comparatively near to shore (section 5.2). They may in part be reworked, particularly in the London Clay at Alum Bay and in sample PB 13 (from the Crepidula Band at Pegwell Bay) where definite reworked species are common. Others must be contemporary, Tertiary specimens. The majority are smooth forms, so it is possible that these would not sink as rapidly as the heavier, ornamented species. They would remain in suspension longer and ultimately form part of the "distant" microflora.

Other rare species are very sporadic through these sediments. They all occur at other localities but although they may be more consistent there, they are never common. These include the genera Restioniidites, Caryapollenites, Ulmipollenites, Alnipollenites, Subtriporopollenites,

Interpollis and Triporopollenites robustus. Restoniidites (and Milfordia incerta) are common in brackish deposits later in the Tertiary (Machin 1971), presumably in intermediate depositional sites. Their scarcity in various environments in the Palaeocene and early Eocene may therefore result from the sporadic occurrence of the parent plants at that time. For the other genera perhaps the plants were scattered through the whole region, rather than occurring in localised stands, and the preservation of this pollen in marine deposits is the result of chance survival in spite of transportation and depositional processes.

c) Reworked species; these occur in all of the marine deposits but are particularly common in the London Clay. They range in age from Carboniferous to Cretaceous with the majority being long-ranging Jurassic-Cretaceous species. The occurrence of individual species is documented in Appendix 2, they include the following:

Carboniferous; densospores, and the genera Lycospora, Florinites, Triquitrites.
Triassic/Rhaetic; striate bisaccate pollen.
Mainly Rhaetic; Ovalipollis ovalis, Rhaetipollis germanicus; Riccisporites tuberculatus, Limbosporites lundbladi.
Early and middle Jurassic; Quadraeculina anellaeformis, Chasmatosporites spp. (up to Callovian), Kraeuselisporites reissingeri.
Long-ranging Mesozoic (mainly Jurassic and Cretaceous); Classopollis torosus, Callialasporites dampieri, I. turbatus, Cerebropollenites mesozoicus, Coronatispora valdensis, Contignisporites problematicus, Podocarpidites sp., Vitreisporites pallidus.
Cretaceous; Pilosisporites trichopapillosus, Trilobosporites spp.

The commonest reworked species in all of the marine deposits is Classopollis torosus. Other species are sporadic in the Thanet Beds but occur consistently in the London Clay in the Leaden Roding and South Lambeth Boreholes and even fairly commonly at Alum Bay. These include the Mesozoic forms Callialasporites dampieri, Cerebropollenites mesozoicus and Vitreisporites pallidus. The richest and most

diverse reworked assemblages occur in the London Clay at Alum Bay. Associated with the species listed above are several which are rare and sporadic in distribution elsewhere but are more consistent here, particularly Lycospora spp., Riccisporites tuberculatus, Quadraeculina anellaeformis and Chasmatosporites spp.

It is conceivable that the Carboniferous spores might come from eroded Rhaetic or early Jurassic deposits since reworked Lycospora sp. and densospores are well known in rocks of those ages (Schulz 1967), alternatively they may be derived from the direct erosion of Carboniferous sediments.

Thus, from the reworking, it is evident that rocks of diverse ages (certainly Rhaetic to Cretaceous and probably also Carboniferous) were undergoing active erosion during the deposition of these early Tertiary marine sediments. The particular abundance of reworked material in the Alum Bay section is a reflection of its more marginal position (Chapter 1.3).

Microplankton.

As Wall et al. (1977) show, different dinoflagellate cyst species have their peak occurrences in distinct environments. Their distribution is determined by a combination of many factors such as salinity, temperature, nutrient supply, water depth, distance from shore. While some species are tolerant of marked variations in salinity and temperature or of turbulence, others require stable conditions. Although it is safe to assume that the distribution of early Tertiary dinoflagellates was controlled by similar factors it is not always easy to determine the critical factors for individual genera.

The work of Downie et al. (1971) and Denison (1977) shows that certain genera or groups of genera are dominant in different formations in the early Tertiary of southern England. In spite of the comparatively small number of microplankton counted in the present study the distribution of the main morphological groups corresponds reasonably well with these earlier reports.

Areoligera/Glaphrocysta group.

This morphological group is most characteristic of the

more arenaceous deposits in the early Tertiary, particularly the Thanet Beds and Woolwich Bottom Bed.

It dominates assemblages in the upper part of the Thanet Beds at Pegwell Bay, forming 40-52% of the microplankton at the top of the Stourmouth Clays, in the Upper Pegwell Marls and the basal Reculver Silts. It is much rarer at other localities, making up no more than 10% of assemblages in the Thanet Beds at Oldhaven Gap, Leaden Roding and South Lambeth and c.15% in the Woolwich Bottom Bed at Oldhaven Gap. Other significant occurrences are in the sandy facies of the Striped Loams at the top of the Woolwich and Reading Beds at Charlton (c.20%) and at Alum Bay. There it is present in silty claystones at the top of the London Clay (AB 58, c.14%) and in sands at the base of the Bracklesham Beds (AB 57, c.30%). Rare specimens also occur in the lagoonal deposits (low energy, brackish) of the Woolwich Shell Beds.

These distribution patterns suggest that the Areoligera/Glaphrocysta group could tolerate low salinity (as could several other groups, especially Apectodinium spp.) but was particularly tolerant of high energy conditions which were too extreme for other brackish water species.

Alisocysta margarita, ?Microdinium sp. 2 Sch. -L. & Ch., Palaeostomocystis laevigata, Horologinella spp.

These species are mainly restricted to the Thanet Beds. All are most persistent at Pegwell Bay, although each is generally less than 5% of the total microplankton. They are all present at the base of the Thanet Beds in the South Lambeth Borehole and at Leaden Roding, although A. margarita, P. laevigata and Horologinella spp. are very rare there. Only Horologinalla spp. and aff. ?Microdinium sp. 2 occur in the Thanet Beds at Oldhaven Gap.

The few records of Horologinella spp. in the London Clay, at Oldhaven Gap and Leaden Roding, may be the result of reworking. However, it is possible, even though both Horoliginella spp. and P. laevigata occur consistently in the Thanet Beds, than they may also be reworked there. The former has a stratigraphic range of Campanian-?early Eocene while P. laevigata is known from the Maastichtian and

Danian, although it also occurs commonly at certain horizons in the lower Landenian (= lower part of the Thanetian) at Gelinden-Overbroek, Belgium (Schumacker-Lambry 1978).

Acritarchs.

Downie et al. (1971) record concentrations of acritarchs in the lower part of the London Clay at Herne Bay and again in the Claygate Beds which overlie it at Kingston, west of London. They compare this dominance of acritarchs with the abundance of acanthomorph acritarchs which Wall (1965) found associated with the transgressive and regressive phases of Liassic cycles of sedimentation. In the fully marine stage the acritarchs were more diverse. The same pattern holds for the London Clay with acanthomorph acritarchs abundant during transgressive and regressive phases while more diverse suites of dinoflagellates (dominated by Spiniferites spp.) are characteristic of open marine conditions.

The Micrhystridium Association (abundant acanthomorph acritarchs) of Downie et al. was recorded in the basal c.30m of London Clay at Herne Bay (1971). All of the London Clay sequences that I have examined from the London Basin come from this lower part of the sequence and contain abundand acritarchs, but so do the samples from the Thanet Beds (except Pegwell Bay) and the Woolwich Bottom Bed. Perhaps the dominance of acritarchs throughout the London Clay at Alum Bay reflects the regressive nature of the upper part of the sequence. Similarly, the upper part of the Thanet Beds (the Reculver Silt) at Oldhaven Gap, which is the most regressive part of this formation, contains a high proportion of acritarchs.

3. INTERMEDIATE SITES OF DEPOSITION.

In the Woolwich facies of the Woolwich and Reading Beds and the upper London Clay to basal Bracklesham Beds at Alum Bay spore/pollen assemblages are diverse since they contain a mixture of local and distant elements. Both sequences were deposited in brackish to shallow marine environments and consequently have microplankton assemblages dominated by species tolerant of restricted conditions.

(i) Woolwich facies of the Woolwich and Reading Beds.

Spores and pollen.

In general the spore/pollen assemblages are very similar to the local microfloras recorded in the lignite horizon at Shorne Wood. It is evident that many species were transported only short distances accumulating in brackish, lagoonal (Woolwich Shell Beds) or nearshore sediments (Striped Loams).

(a) Local elements within the microflora.

These are primarily species which are characteristic of the P/S Association in the lignite at Shorne Wood. Platycaryapollenites platycaryoides remains very common to abundant and is associated with fairly common Sparganiaceaepollenites spp., Laevigatosporites spp., Monocolpopollenites tranquillus and Nudopollis spp./Plicapollis pseudoexcelsus. The latter is common at Shorne Wood and at the base of the Shell Beds at Swanscombe and Charlton but becomes rare higher in the sequence. Further west (at South Lambeth) and north (Leaden Roding) the group is generally rare throughout the Woolwich and Reading Beds.

Several other species which occur in the lignite remain fairly common in the Shell Beds at Shorne Wood but are rare at Charlton, Swanscombe and in the Shell Beds at South Lambeth, particularly Gallopollis minimus and Pistillopollenites mcgregorii while Pandaniidites texus, rare but consistent at Shorne Wood and Charlton is very sporadic elsewhere.

(b) Intermediate elements within the microflora.

Three genera which are very characteristic of the Woolwich Shell Beds and Striped Loams (except at South Lambeth), although they are usually only rare or fairly common, are Dicolpopollis, Restoniidites and Interpollis. Dicolpopollis was not recorded in the lignite and the others occur there sporadically. The concentration of these forms in this area, centred on Shorne Wood, and their virtual absence from both the lignite and the marine (distant) depositional sites discussed above, suggests that they are of comparatively local origin. In contrast, the small tricolpate and tricolporate

pollen which is common at each of the localities, probably comes from an extensive regional flora and may be both of local and distant origin.

(c) Distant elements within the microflora.

It is apparent from the diversity of the microflora that pollen was being transported into the lagoon from a variety of sources. The local elements are very well represented while the distant elements mainly comprise very common Inaperturopollenites spp. (including I. hiatus) and possibly rare bisaccate pollen. The latter may in fact be of local origin since it does occur rarely in the lignite at Shorne Wood and there is no appreciable increase in abundance in the Shell Beds. Alternatively, if it is from a distant source, it is greatly overshadowed by the wealth of local pollen.

Reworking is rare, it comprises mainly Classopollis torosus, Caliallasporites dampieri and Cerebropollenites mesozoicus.

The Leaden Roding borehole is in an area that is usually considered to be within the Reading facies of the Woolwich and Reading Beds (Figure 1.4). Certainly there are no typical Woolwich Shell Beds in the borehole, silty clays and sands predominate. The spore/pollen assemblages mainly comprise distant elements, tricolpate and tricolporate pollen, abundant Inaperturopollenites hiatus and bisaccate pollen (as common as in the marine Thanet Beds and London Clay). Species which are local in the Woolwich facies are rarer here, most noticeably Platycaryapollenites platycaryoides, Sparganiaceaepollenites spp., Monocolpopollenites spp., Nudopollis/Plicapollis spp. and monolete spores. These, with the very rare specimens of Pistillipollenites mcgregorii, Dicolpopollis sp. and Pentaporoites belgius (very rare even in the Woolwich facies) are all distant elements at this locality.

Microplankton.

Microplankton assemblages from the low energy, brackish deposits of the Woolwich Shell Beds and the laminated beds at the base of the Striped Loams are dominated by species which are known to tolerate brackish conditions, species of Apectodinium and the ?Trichodinium group. The former, which

includes A. homomorphum, A. parvum and rare A. hyperacanthum, is very abundant. It usually occurs at 20% or more but reaches peaks of 87% at Shorne Wood, 72% at Charlton, and 85% at South Lambeth. ?Trichodinium group is much more variable, it is comparatively rare at Shorne Wood (around 3% except for an occurrence of 12.6% at JL 910), it ranges from 2.4% - 46.4% at Charlton and 8.2% - 29% at Swanscombe. The most westerly occurrence for both groups (in the London Basin) is at South Lambeth where Apectodinium spp. are well represented (see above) and ?Trichodinium group occurs at c.10%. Interesting changes occur in the upper, sandy part of the Striped Loams at Charlton (Fig.2.4). Apectodinium spp. are abundant in sample CH 17 but are absent from CH 21 which has a mixed assemblage of Areoligera/Glaphrocysta spp. and acritarchs. ?Trichodinium group is absent from both samples. Denison (1977) also records Apectodinium spp., without the Trichodinium group, in the more arenaceous deposits towards the top of the Bottom Bed at Charlton. He suggests therefore, that Apectodinium spp. are more tolerant of turbulence, and a high energy environment, than ?Trichodinium group. The presence of rare specimens in the ?Reading facies of the Woolwich and Reading Beds at Leaden Roding (LR 24, LR 22 and LR 17), indicates brackish conditions at that locality.

From the fauna there is evidence of fluctuations in salinity through the Woolwich Shell Bed. Some of these are reflected in the microplankton assemblages. Oysters, indicating less brackish conditions, occur at Swanscombe in sample SW 30 and there is a marked increase in Spiniferites spp. (a more open marine genus) in the same sample. This relationship is not so obvious at Charlton where samples CH 5 and CH 6 contain oysters but, although Spiniferites spp. are present they show no associated increase. Freshwater faunas are present in CH 8 at Charlton (particularly Hydrobia). Here there is a marked decline in the total microplankton percentage and an increase in ?Trichodinium spp. No freshwater algae (e.g. Pediastrum) were recorded however. In contrast the freshwater 'marl' at Swanscombe, SW 33, has 24% Pediastrum sp. The highest percentages of Pediastrum were recorded in the Shorne Wood section where JL 905 and JL 942 have 65% and 84% respectively. In both cases there are no obvious

differences in the accompanying spore/pollen assemblages.

(ii) Upper London Clay to basal Bracklesham Beds at Alum Bay.

There is a marked change in the microflora within the section examined at Alum Bay. As described above, the lower part of the London Clay (samples AB 47-AB 56) contain a microflora indicative of a distant depostional site. The upper part of the section comprises the most regressive part of the London Clay together with the basal Bracklesham Beds; sands and laminated beds with lignitic horizons (AB 58-AB 64). Here distant elements, including reworked species, decline but there is an increase in several species which only occur sporadically in the underlying London Clay. These are believed to be of comparatively local origin here. The upper London Clay to basal Bracklesham Beds are considered to have been intermediate in terms of depositional site since the microflora is diverse and comprises a mixture of local and regional elements.

(a) Local elements in the microflora.

These include rare to fairly common Monocolpopollenites tranquillus, Dicolpopollis spp. and Interpollis spp. with common Nudopollis/Plicapollis spp. and rare Pistillipollenites mcgregorii, Spinizonocolpites spp. and Tricolporopollenites iliacus. Except for the last two species this group is also significant in the Woolwich Shell Beds. All are assumed to have been produced by plants growing fairly near to the depostional site. Machin refers to pollen of Plicapollis pseudoexcelsus type as Myrica sp. A. (1971, plate 2, no.23) and suggests it is probably a swamp species. Its relative abundance here at Alum Bay, in contrast to its virtual absence from the more marine deposits below, and its occurrence in similar quantities in the comparable intermediate depositional site of the Woolwich Shell Beds, point to a local origin. Spinizonocolpites spp. (Nipa-type pollen) is rare but consistent here. This unit correlates with the London Clay which outcrops at Sheppey (Divisions D-E) and which contains such abundant Nipa fruits (King 1981). No Spinizonocolpites spp. has been found in the London Basin however. It is probable that the parent plants lived at

the edge of the depostional basin, at what is now the western end of the Hampshire Basin, and that their pollen accumulated in sediments near to where the plants grew while the fruits floated long distances before finally sinking and being incorporated into the sediment.

(b) Distant elements in the microflora.

These are much more difficult to define than in the underlying marine environment. Inaperturopollenites hiatus is generally less common than in the earlier London Clay but at least a proportion of it is probably from distant sources. Bisaccate pollen is generally rare, perhaps because of an over-representation of species of more local origin. Tricolpate pollen (liblarensis/microhenrici group and undifferentiated species) is much more common than in the lower part of the London Clay and is generally diverse. This group probably includes some elements derived from the regional vegetation as well as others from more local sources.

(c) Other significant species.

Another characteristic of this unit is the appearance of several very rare species which are stratigraphically useful. Their ranges are described below (p.276).

A single specimen of Spinizonocolpites spp. was recorded in the London Clay (Division B2, sample AB 54), but the species does not occur consistently until this upper London Clay/basal Bracklesham Beds unit. Other species which appear within the interval are Diporites iskaszentgyorgyi, Brosipollis striatobossus, Thomsonipollis magnificus, T. magnificoides and Anacolosidites pseudoefflatus. Several of the tricolpate and tricolporate species also seem to be more characteristic of these and younger deposits but the detailed distribution of individual species was not recorded.

(d) Microplankton and other algae.

These shallow marine deposits contain only rare microplankton, mainly acritarchs but with Areoligera/Glaphrocysta spp. in samples AB 58 to AB 60 and Apectodinium spp. at AB 57. The peak occurrence of the former coincides with arenaceous deposits, AB 57, confirmation of its tolerance of turbulent conditions. The presence of Apectodinium spp. and Ovoidites ligneolus in the same sample suggests a

brackish environment with influx of freshwater. Freshwater influence is indicated at other horizons by the presence of Ovoidites sp., Schizosporis spp. or Pediastrum sp.

4. STRATIGRAPHICALLY RESTRICTED SPORES AND POLLEN.

In spite of the rich and diverse microfloras recovered from the early Tertiary sediments of southern England comparatively few species are stratigraphically restricted and these are always rare. As shown in the systematic section (Chapter 4) many range throughout the interval examined while others range from the late Cretaceous into the Neogene.

Several species are restricted to the Thanet Beds and Woolwich and Reading Beds including;

Vacuopollis spp. (V. concavus and V. semiconcavus); persistent in the Thanet Beds at Pegwell Bay, Oldhaven Gap and South Lambeth. Single specimens recorded in the Woolwich Marine Bed at Oldhaven Gap (OG 11) and in the Reading Bottom Bed at Pincents Kiln (PK 21). Góczán et al. list the range of V. concavus as Maastrichtian-early Eocene. Gruas-Cavagnetto (1976a) does not record it above the Thanet Beds. V. semiconcavus is described from the early Campanian (Góczán et al. 1967).

Stephanoporopollenites hexaradiatus subsp. semitribinae. Very rare, single specimens recorded from the Thanet Beds at Pegwell Bay (PB 11, PB 12), South Lambeth (SL 29) and from Reading Bottom Bed at Pincents Kiln (PK 20). Reported from the Montian to Thanetian (Pg.-Zones 7a-10, Krutzsch 1970a).

Stephanoporopollenites hexaradiatus subsp. tribinae. Rare, isolated specimens recorded from the Thanet Beds at Pegwell Bay (PB 11), Woolwich Marine Bed at Oldhaven Gap (OG B), Reading Bottom Bed at Pincents Kiln (PK 4, PK 20) and from the Woolwich Shell Bed at Charlton (CH 6, listed in "Others" in Table A2.3, Appendix 2). Reported from the middle Palaeocene to lower Eocene in central Europe (Pg.-Zone 7b-13a, Góczán et al. 1967) and to the top of the Thanetian Zone III of the Paris Basin (Kedves 1969). Gruas-Cavagnetto 1976a) records it only in the Thanet Beds and Woolwich Bottom Bed at Herne Bay.

Trudopollis hammenii. Rare in the Thanet Beds at Pegwell Bay, Oldhaven Gap, South Lambeth and Leaden Roding. A single specimen was recorded in the Reading Bottom Bed at Pincents Kiln (PK 20). Reported to range to the top of the Thanetian (I.G.C.R. Project 124, The northwest European Tertiary Basin, Report No. 6, Dec. 1980). Roche (1973) reports it from both Landenian L1 and L2 (the latter is equivalent to the Sparnacian = Woolwich and Reading Beds).

Pentaporoites belgicus. Extremely rare, recorded only in the Woolwich and Reading Beds. Single specimens noted in the Woolwich Shell Beds at Shorne Wood (JL 887), at Charlton (CH 5, CH 8) and the Striped Loams (CH 16), also in undifferentiated Woolwich and Reading Beds at Leaden Roding (LR 22). This is the first record of this species in the British Tertiary. Reported from Pg.-Zone 11 (basal Eocene = "Sparnacian") (Kr. & Vanh. 1977). Krutzsch (1970a) describes it as rare and reports it from the lowest Eocene (Pg.-Zone 11) to middle Eocene.

The second group of species which are at all restricted stratigraphically first appear towards the top of the London Clay at Alum and persist into the Bracklesham Beds. On the Continent most of these range from within the Sparnacian upwards. These forms have not been recorded at any other section in the present study.

Spinizonocolpites spp. Single record at AB 54 (London Clay Division B), consistent from AB 58 (Division D) through basal Bracklesham Beds. Reported from upper Sparnacian and younger (Gruas-Cavagnetto 1977).

Diporites iskaszentgyorgyi. Rare specimens recorded from London Clay Division D (AB 58) and basal Bracklesham Beds (AB 64). Reported from the Sparnacian of the Paris Basin, the early Eocene of Hungary and southern England (Lower Bagshot Beds and Bracklesham Beds) and from the Bournemouth Freshwater Beds (Gruas-Cavagnetto 1977).

Anacolosidites pseudoefflatus (same reported distribution as A. efflatus). Single specimen from basal Bracklesham

Beds (AB 60). Reported from Pg.-Zone 13-18, early Eocene, not present in basal Eocene (=Sparnacian) (Krutzsch 1970a). Gruas-Cavagnetto (1976a) reports A. efflatus from the Upper London Clay from Lower Swanscombe, Southampton.

Brosipollis striatobossus. Single specimen recorded in the Bracklesham Beds (AB 60). Rare specimens reported from Pg.-Zone 11-13a (=Sparnacian + basal Eocene) and irregular occurrence from Pg.-Zone 13b-16 (early-middle Eocene) Krutzsch (1970a). Present in the early Eocene of the Paris Basin (Gruas-Cavagnetto 1977) and in the Lower Bagshot Beds of Dorset (Gruas-Cavagnetto 1976a).

Thomsonipollis magnificus and T. magnificoides. Single specimens of each species recorded in the basal Bracklesham Beds (AB 60). This species is very characteristic of the early Eocene of Germany (Pg.-Zones 13a, 13b and 14) but no comparable abundance level has been recorded in the rest of northwest Europe (Krutzsch 1970a). Common in the late Palaeocene Rockdale Lignite in Texas (Elsik 1968, Nichols & Traverse 1971).

Two species were only recorded in the samples examined from higher in the Bracklesham Beds. Parsonidites britannicus (AB 68, early Eocene) was described from the Bournemouth Freshwater Bed (early Eocene) by Gruas-Cavagnetto (1976a). Polyatriopollenites stellatus (AB 70, middle Eocene) is known from the middle Eocene to Miocene in central Europe (Thomson & Pflug 1953) from the late Eocene and Oligocene of the Paris Basin and the Middle Headon Beds (late Eocene) and Upper Hamstead Beds (middle Oligocene) of the Hampshire Basin (Gruas-Cavagnetto 1977).

5. DINOFLAGELLATE ZONES RECOGNISED.

The detailed distribution of individual species was not recorded in the present investigation. It has been possible, however, to recognise several of the dinoflagellate zones already described in the literature.

Deflandrea speciosa Zone. This was defined by Caro (1973) in the southern Pyrenees (northeast Spain), on the presence

of D. speciosa in an interval beneath the basal occurrence of Apectodinium hyperacanthum. The top of the zone is in the calcareous nannoplankton zone Heliolithus riedeli (see Fig.1.2) which coincides with the English Thanetian (i.e. Thanet Beds)but its base is not defined.

Alisocysta margarita Informal Zone of Knox et al. (1980). This is recognised in Palaeocene sequences in the central North Sea and is characterized by the presence of A. margarita, Deflandria dartmooria and Hafniasphaera septata (Cooks. & Eis.) Hansen. The authors consider it to be of Thanetian age and probably equivalent to the Deflandrea speciosa Zone as depicted by Costa & Downie (1976). Elements which chatacterise both of these independantly defined zones occur in the Thanet Beds. As discussed above (Chapter 4.2) the species D. speciosa, D. oebisfeldensis and D. dartmooria are very similar, if not identical. This form is present in the Thanet Beds at Pegwell Bay, Oldhaven Gap and South Lambeth. Alisocysta margarita is associated with it at Pegwell Bay and is also present in the Thanet Beds at Leaden Roding. Hafniasphaera spp. (which include H. septata) also occur in the Thanet Beds at Pegwell Bay, Oldhaven Gap, South Lambeth and Leaden Roding. But it must be emphasised that H. septata s.s. has not been separated from similar morphological types and this group is also recorded in the London Clay at South Lambeth.

Apectodinium hyperacanthum Zone (Costa & Downie 1976), an interval between the incoming (base) of the genus Apectodinium to the first occurrence of Wetzeliella meckelfeldensis. It is recognised in Britain in the Woolwich Beds at Charlton, Erith and Upnor and in the base of the London Clay at Whitecliff Bay and Herne Bay (Costa & Downie 1976, p.600). The Wetzeliella astra Zone was later established between these two zones (Costa et al. 1978) and replaces the A. hyperacanthum Zone in these last two sections. King (1981, p.113) suggests that the A. hyperacanthum/W. astra zone boundary proably lies within the lowest part of his Division A2 (=Walton Member); this is the lowest part of the London Clay present at Herne Bay and Whitecliff Bay.

The zone is recognised from northeast Spain (Caro 1973), from the upper Landenian of Belgium and the upper part of the Palaozan, Untereozan 1 in Germany (Costa et al. 1976). Gruas-Cavagnetto (1968) records similar assemblages from the Paris Basin; including the Sables de Sinceny (equated with Blackheath and Oldhaven Beds by Curry et al. 1978) and the Sparnacien inferieur at Mont-Bernon. More recently the A. hyperacanthum Zone has been recognised in various parts of the North Sea; Knox et al. record it in the U.K. sector of the central North Sea, Ioakim (1979) has a similar zone in the northern North Sea and Heritier et al. (1979) recognise a Wetzeliella hyperacantha and W. homomorpha assemblage (zone nt IIa lower) in the Frigg gas field, northern North Sea. This is probably equivalent to the A. hyperacanthum Zone recognised onshore in northwest Europe but the authors propose a Thanetian age.

In all of the occurrences listed above other species of Apectodinium tend to be more common than A. hyperacanthum. The same is true of assemblages from this zone in the Woolwich Shell Beds in the London Basin. Here assemblages are dominated by A. homomorphum, A. parvum and A. quinquelatum, with only very rare A. hyperacanthum.

Costa & Downie (1976) establish a series of zones based on various genera in the Wetzelliaceae. Several of these are reported through the London Clay.

Unfortunately I have recorded very few specimens of the Wetzelliaceae in the London Clay sections I have examined. The only useful form is Dracodinium solidum, present in Division B at Alum Bay (AB 52, AB 54), which indicates the presence of the Dracodinium similis Zone at this level. King (1981, Text-fig.52) equates the base of Division B with the base of this zone.

6. SUMMARY OF MAIN FEATURES OF THE EARLY TERTIARY MICROFLORA IN SOUTHERN ENGLAND.

In sections examined from the London Basin there is no major change in the spore/pollen flora from the Thanet Beds to the top of the London Clay. The majority of species recorded persist through the whole interval and assemblages from the Thanet Beds and the London Clay are very similar.

Apparent floral differences in the Woolwich and Reading Beds are due to quantitative variations, different species dominate in each facies. Thus two distinct spore/pollen microfloral associations occur. a) At the western end of the London Basin, in the Reading facies, a mixed microflora characterises the Reading Bottom Bed and the succeeding fluvial deposits. The association (M/I) contains diverse tricolpate and tricolporate pollen, Momipites group and several other triporate species which are locally dominant. The most typical forms are species of Compositoipollenites, Intratriporopollenites and Nyssapollenites with Triatriopollenites confusus (+ T. subtriangulus), Tricolporopollenites mansfeldensis and Rhoipites sp. A. The spores and pollen of this association are believed to have been produced by plant communities growing close to the depositional site. The upper part of the association, in the fluvial deposits, may be contemporaneous with the spore and pollen association (P/S) which characterises deposits of Woolwich facies in the central part of the London Basin. It occurs in the lignite at the top of the Bottom Bed and (as the P/A/T Association) persists through the Woolwich Shell Beds.
b) This second distinctive microflora (P/S and P/A/T Associations) is dominated by Platycaryapollenites platycaryoides with subsidiary Sparganiaceaepollenites spp., Laevigatosporites spp., Monocolpopollenites tranquillus, Nudopollis/Plicapollis pseudoexcelsus, Pistillipollenites mcgregorii and Dicolpopollis spp. This microflora is also considered to be of local origin. Thus two distinct plant communities existed in the London Basin at approximately the same time, in the late Palaeocene. There is slight evidence of mixing of spores and pollen from both communities, in the Woolwich and Reading Beds of the Leaden Roding Borehole.

However, when assemblages from the Alum Bay sequence are compared with those from the London Basin, there is a change in the microflora towards the top of the London Clay (at the top of Prestwich's Bed 6 (1846)). The new association (D/S) persists through the lower Bracklesham Beds.

The most obvious quantitative changes are the decline in bisaccate pollen, and in reworked taxa (especially

Classopollis torosus and Spheripollenites spp., which is probably reworked) and a marked increase in small tricolpate pollen. Association D/S has much in common with the P/S Association recorded in the Woolwich Shell Bed and Striped Loams, particularly in the relative importance of Monocolpopollenites tranquillus, Dicolpopollis spp. (probably Palmae) and Nudopollis/Plicapollis pseudoexcelsus and in the presence of Interpollis spp. and Pistillipollenites mcgregorii. Both microfloras comprise spores and pollen which accumulated near to the source vegetation as well as other, more regional species, and both sequences were deposited in nearshore, probably brackish, environments. The microfloral change at Alum Bay may therefore be a response to facies change.

Compared with the underlying London Clay C(R) Associations at Alum Bay, several additional species appear or become more common, in the D/S Association. Spinizonocolpites spp. become consistent while very rare specimens of Analocodites pseudoefflatus, Brosipollis striatobrossus, Thomsonipollis spp. and Diporites iskaszentgyorgyi appear. Samples from this level were included in the London Clay by Ma Khin Sein (1961). It is interesting to note that, according to Chandler (1961, p.61), she found no marked floral changes to be discernible throughout the deposition of the London Clay.

Published data are generally too imprecise for the exact stratigraphic bases of these species to be pin-pointed within the early Tertiary. Their appearance at this level may be controlled by facies, since rare specimens are recorded in the Sparnacian of the Paris Basin although they are all absent from the Late Palaeocene Woolwich Shell Beds/ Striped Loams, the most similar facies in older British sequences. The absence of Spinizonocolpites spp. from the London Clay in the London Basin, in spite of the abundance of Nipa fruits in the upper part of the formation points to some facies control in the distribution of this pollen type. All the evidence suggests that Spinizonocolpites spp. (and Nipa fruit) appeared in northwest Europe in the Sparnacian (Durand and Ollivier-Pierre 1969). In the samples I examined from Alum Bay the genus first appears (AB 54, single specimen) in King's Division

B2 of the London Clay (1981) but does not become consistent until Division D.

Since I have argued against assigning fossil pollen to extant genera I am reluctant to speculate on the climatic conditions which prevailed during the deposition of these early Tertiary sediments although much has been written on the subject (Sein 1961, Chandler 1964, Chaloner 1968, Daley 1972, Gruas-Cavagnetto 1977, Collinson et al. 1981). The following points can be made, however. Previous climatic interpretations have assumed for the fossil plant the climatic and ecological tolerances of its presumed living relatives (Sein 1961, Machin 1971, Gruas-Cavagnetto 1977). Thus, traditionally, tropical elements are taken to include Nipa and Iodes; essentially tropical and subtropical forms include Salvinia, Azolla, Calamus, Reevsia, Sapotaceae; warm temperate to subtropical elements include Platycarya, Nyssa, Taxodium, Glyptostrobus and temperate forms include Alnus, Carya, Tilia (Gruas-Cavagnetto 1977). Pollen which is believed to have affinity with each of these taxa occurs at various levels in the late Palaeocene to early Eocene of southern England and all except those comparable to Nipa, Salvinia, Calamus and the Sapotaceae occur in every formation.

It is difficult to assess the relative significance of each of these climatic indicators in such mixed assemblages. Taxodium-type pollen occurs commonly at some level in all formations for example. Platycaryapollenites (Platycarya-type) forms part of the background assemblage from the Thanet Beds to London Clay, although it is only abundant in the Woolwich facies of the Woolwich and Reading Beds. Platycarya however, is also a frequent macrofossil in the London Clay (Machin 1971). Bisaccate pollen (in part probably equivalent to Pinus) is common to abundant in Thanet Beds, where Pinus spp. are the most common plant macrofossil (Chandler 1964). Perhaps this points to a relatively local source (but see discussion on Nipa above, p.281). Yet bisaccate pollen is also very common through most of the London Clay (compare Figs. 5.2, 5.3, 5.11, 5.13 and 5.16). The tropical indicators in the microflora are generally rare throughout, even in the London Clay where macrofossil evidence has been used to suggest tropical conditions (Chandler 1964). Even so,

Compositoipollenites spp., with probable affinity to Iodes, are locally very common at Cold Ash Quarry.

As Daley points out (1972, p.181, following Dorf, 1959 and Reid and Chandler, 1933), climatic interpretations should be based on the total plant assemblage. He concludes that the mixed London Clay flora is related to a climatic type which is apparently unrepresented today, with temperatures lower than is normal for strictly tropical climates, with little seasonal variations in temperature, particularly no frosts, and with very high rainfall and humidity.

Nevertheless it seems unlikely that all Tertiary representatives of modern genera had exactly the same ecological or climatic requirements as their living relatives (Dilcher 1973, Graham 1973, Gruas-Cavagnetto 1977). Climatic interpretations therefore remain controversial.

I believe the changes in relative abundance of individual taxa recorded in this early Tertiary sequence (Thanet Beds to London Clay) are related to facies rather than climatic fluctuations. From the microfloral evidence it seems likely therefore that similar climatic conditions prevailed during the deposition of the early Tertiary sequence from the Thanet Beds to the base of the Bracklesham Beds.

There is greater qualitative variation in the microplankton assemblages. Although many species persist through the whole interval there are distinct associations which, although influenced partly by lithology and salinity, are also stratigraphically significant. Thus the Thanet Beds are dominated by long-ranging species of Areoligera and Glaphrocysta associated with Deflandrea dartmooria/oebisfeldensis but also have a group of species which are mainly restricted to this formation (Alisocysta margarita, ?Microdinium sp. 2 Sch.-L. and Ch., Horologinella spp. and Palaeostomocystis laevigata).

Assemblages from the Woolwich Shell Bed and basal Striped Loams are dominated by Apectodinium spp. characteristic of the A. hyperacantha Zone (Costa & Downie 1976) and of stratigraphic significance in the late Palaeocene. In sections examined in the present investigation London Clay

assemblages are dominated by acritarchs and lack a distinct dinoflagellate cyst association. However, the work of Williams & Downie (1966a,b) and Costa & Downie (1976) has shown the presence of age restricted species.

5.4 BRIEF COMPARISON WITH OTHER EARLY TERTIARY MICROFLORAS.

From the details of distribution given in the systematic section (Chapter 4) it is apparent that most of the taxa recognised during this study are already well known from early Tertiary sequences in adjacent areas on the Continent. Most work on the spores and pollen has been carried out in France, Belgium and Germany (Chapter 3). There are also considerable similarities with microfloras from eastern and southeastern U.S.A. (Elsik 1968, Nichols & Traverse 1971, Frederiksen & Christopher 1978, Frederiksen 1979).

The similarity between dinoflagellate cyst associations of southern England and those recorded on the Continent is also discussed above (Chapter 5.3, section 5). The Thanetian assemblages from Belgium deserve more comment however.

Schumacker-Lambry and Chateauneuf (1976) describe assemblages from the Marne de Gelinden (Stratotype of the Heersian, i.e. lowest part of the Landinian, equivalent to the lower part of the Thanet Beds (Curry et al. 1978, Table 2). The authors describe assemblages dominated by Spiniferites (as Hystrichosphaera) and Achomosphaera, forming 20%-65%, with the Areoligera/Glaphrocysta (as Cyclonephelium) group up to 25% and acritarchs forming about 30% of the total microplankton. Deflandrea spp. are rare but include D. speciosa. They suggest the Gelinden association as a whole is most similar to the Thanetian of the Paris Basin as described by Gruas-Cavagnetto (1972), the Ypresian of Belgium (De Coninck 1968) and the Spiniferites and Areoligera assemblages of Downie et al. 1971. Certain of the elements which are characteristic of the Thanet Beds (although generally rare) are also recorded. However, these species were not listed by Downie et al. and therefore not considered for comparison. These include Palaeostomocystis laevigata, ?Microdinium sp. 2, Inversidinium exilimurum and Alisocysta margatita (as Eisenackia circumtabulata). The latter alone would preclude correlation with either the Ypresian of Belgium or the Spiniferites

association (in the London Clay) of southern England. There is however good correspondence with the Thanet Beds assemblages, particularly at Pegwell Bay.

Spore/pollen assemblages from the Marne de Gelinden are described by Schumacker-Lambry and Roche (1973). In the relative proportions of individual species they differ from the Thanet Beds assemblages, particularly in the low percentages of Inaperturopollenites spp. (1% or less). Small tricolpate pollen (Tricolpopollenites hians = variabilis/parvus group herein) with other tricolpate pollen and Tricolporopollenites cingulum form 53% of the total; Triatriopollenites spp. (including Platycaryapollenites platycaryoides) form 15%, bisaccate pollen only 5% and the Normapolles 7%. However, amongst the rarer species are several which are also characteristic of the Thanet Beds, although they are rare there, in particular Trudopollis hammenii, Vacuopollis semiconcavus (which is limited to the Heersian in Belgium) and Stephanoporopollenites hexaradiatus subsp. tribinae (does not range above the Heersian in Belgium, although in the Paris Basin it is known from the Thanetian III and in central Europe it ranges into the early Eocene (p.169). The authors consider that their assemblages are very similar to those from the different formations of the Thanetian Zone II of the Paris Basin (=Thanet Beds in part) but are different from the Thanetian Zone III assemblages (=Woolwich and Reading Beds in part).

In her many papers on the early Tertiary of the Paris Basin Gruas-Cavagnetto has listed a rich and diverse microflora but generally without quantitative data. Her early paper, (1968), is useful in providing percentage frequency counts for samples from various Sparnacian horizons, which she first described in 1967(c). The sediments include lignites, clays with molluscs and pebbly sands and are similar to the British Woolwich and Reading Beds and Blackheath and Oldhaven Beds. Assemblages contain similar species to those recorded in the London Basin but the relative proportions are generally different. The spore/pollen assemblages from the clays and sand, for example, in the Sable de Sinceny at Sinceny, and sections at Saint-Maurice and Thionville-sur-Opton, are dominated by Plicapollis pseudoexcelsus, and

Platycaryapollenites platycaryoides (as Triatriopollenites coryphaeus), both usually 30% or more with subsidiary amounts of tricolpate pollen, and Subtriporopollenites spp. At Saint-Maurice P. platycaryoides dominates forming c.60% of assemblages which, as well as the species listed above contain Intratriporopollenites spp., 5-10% and Palmae (including Monocolpopollenites tranquillus) c.5%. At other sections Plicapollis psuedoexcelsus predominates over Platycaryapollenites platycaryoides. Although P. pseudoexcelsus is fairly common in the Woolwich Shell Beds at Shorne Wood it is comparatively rare in the Shell Beds at other sections; it never reaches the dominance characteristic of the Paris Basin samples. Assemblages from the lignites are also generally dominated by different genera. At Saint-Maurice and at Arpenty, 2 km. away, lignites have c.15% and 45% of Triporopollenites robustus, c.10% of Triporopollenites megagranifer, and 9-15% of Plicapollis pseudoexcelsus with (at Arpenty) 18% Tricolporopollenites cingulum and 3% palm pollen (including 2% Dicolpopollis luteticus). Both of these groups are absent at Saint-Maurice. Sparganiaceaepollenites spp., so characteristic of the Woolwich facies in the London Basin, is occasionally present, as in the Guitrancourt section but exceeds 10% only in the sands and lignitic sands at Saint-Leger-aux-bois. Here it is associated with Ovoidites spp. in the sandy lignite. In the section at Banthelu (lignitic clays) assemblages are dominated by spores (c.50%) particularly Laevigatosporites haardti, Leiotriletes adriennis and Cicatricosisporites dorogensis. Although forms similar to the first two are significant in the Woolwich lignites at Shorne Wood they never reach such abundance. Gruas-Cavagnetto (1967c) suggests that the assemblages with abundant T. robustus, M. tranquillus, Sparganiaceaepollenites and spores are all of local origin while assemblages with abundant P. platycaryoides and P. pseudoexcelsus were produced by vegetation growing at the edge of a lake or marsh.

In spite of these differences in relative proportions the overall microflora is very similar to that in the Woolwich facies in the London Basin. Microplankton assemblages are also comparable, Apectodinium spp. dominate, sometimes up to 96% as at Mont-Bernon. They are all typical of the

Apectodinium hyperacantum Zone. Costa et al. (1978) include the whole of the French Sparnacian, up to the Sable de Sinceny, in this zone.

Krutzsch and Vanhoorne (1977) illustrate spores and pollen from lignite samples from the Upper Landinian of Belgium, from Epinois and from a borehole at Locksbergen. These also are dominated by Plicapollis pseudoexcelsus. Various species of Platycarapollenites (as Platycaryapollis) are recognised including P. levis (P. platycaryoides in part). The latter is described as occurring regularly in the Epinois section and Locksbergen borehole. Tricolpate and tricolporate pollen are more diverse than in the lignite at Shorne Wood but several species are common to all three sections, particulary Sparganiaceaepollenites cuvillieri, Subtriporopollenites constans magnus, Pistillipollenites mcgregorii (abundant at some levels), Nudopollis endangulatus + N. terminalis, Tricolporopollenites parmularius, Hydrosporis levis, Leiotriletes spp. and Laevigatosporites spp. (probably L. haardti and L. discordatus in part). Very rare elements in the Belgian lignites, Pentaporoites belgicus and Stephanoporopollenites hexaradiatus subsp. tribinae also occur very rarely in the Woolwich Shell Bed, but do not range higher.

Krutzsch and Vanhoorne consider these samples to be from Pg.-Zone 11 of basal Eocene age. However, the Upper Landenian is usually correlated with the French Sparnacian and Woolwich and Reading Beds, which are considered to be of late Palaeocene age (Roche 1970, Curry et al. 1978). Although the microfloras have different dominant species there is general similarity in the consistant and rarer forms.

Certain elements which are characteristic of the late Palaeocene and early Eocene in northwest Europe are also well known from eastern or southeastern U.S.A., particularly Pistillipollenites mcgregorii (first described from north America), Normapolles, including various species of Nudopollis, also Carya pollenites spp., Triporopollenites robustus, Restoniidites spp. (Elsik 1968) and Spinulaepollis spinosus (as Sernapollenites duratus Stover 1966). More recent papers reveal other similarities, Interpollis microsupplingensis and Anacolosidites sp. (Frederiksen 1979); Compositoipollenites rhizophorus subsp. burghasungensis (as Malvacipollis

sp.) and Subtriporopollenites anulatus subsp. nanus (Frederiksen 1980).

Other genera, which are characteristic of the north American assemblages have not been reported in Europe, most notably Choanopollenites Stover 1966, Holkopollenites Fairchild 1966, Kyandopollenites Stover 1966 while Thomsonipollis spp., which is common in this area, is rare in northwest Europe, except in Germany (Krutzsch 1970a). Several recent papers on early Tertiary palynology of eastern and southeastern U.S.A. concentrate on the primitive Juglandaceae (Nichols & Ott 1978; Frederiksen & Christopher 1978). Many species are recognised and the group appears to be more diverse there than in Europe.

Thus the late Palaeocene and early Eocene microfloras of southern England are very similar to those recorded at similar stratigraphic levels in adjacent areas on the Continent and appear to have considerable similarity with the early Tertiary microfloras of southeastern U.S.A.

CHAPTER 6: GENERAL CONCLUSIONS

1. The late Palaeocene to early Eocene deposits of southern England (Thanet Beds to basal Bracklesham Beds) contain rich and diverse spore/pollen assemblages, some 200 species are distinguished. The microflora is generally similar to those already known from the Continent.

2. There is no marked change in the microflora within the interval investigated. Several common forms range throughout, particularly bisaccate pollen, Inaperturopollenites hiatus, Cupuliferoidaepollenites liblarensis/microhenrici group, tricolpate pollen of the variabilis/parvus group, Tricolporopollenites cingulum group, Platycaryapollenites platycaryoides and Nudopollis/Plicapollis pseudoexcelsus group.

3. There are changes in the relative abundance of the common forms listed above and of other rare species which may locally become abundant and dominate assemblages. These changes are considered to be related to the distribution patterns of the parent plants and to the influence of sedimentological and other processes during deposition. They are not thought to be the result of climatic change.

4. From these variations a series of distinct microfloral associations may be recognised. The most significant of these are:

   (a) The Thanet Beds are characterised by long-ranging spores and pollen (particularly Inaperturopollenites matus and bisaccate pollen), associated with a distinctive dinoflagellate suite, the Areoligera/Glaphrocysta group.

   (b) The lignite in the Woolwich facies of the Woolwich and Reading Beds has an assemblage dominated by Platycaryapollenites platycaryoides or Sparganiaceaepollenites spp. This is believed to be a local microflora.

   (c) A second local association occurs in the Reading facies of the Woolwich and Reading Beds, at the western end of the London Basin. This is

characterised by triporate pollen, particularly Triatriopollenites confusus with Intratriporopollenites spp. and Compositoipollenites spp.

(d) The spore/pollen assemblages in the Woolwich Shell Beds are similar to those in the lignite. This association is distinguished by abundant dinoflagellates, Apectodinium spp., characteristic of the Apectodinium hyperacanthum Zone (Costa & Downie 1976).

(e) Most of the London Clay is characterised by long-ranging spores and pollen, with common reworking and microplankton assemblages dominated by acritarchs.

(f) Towards the top of the London Clay and in the overlying basal Bracklesham Beds at Alum Bay the spore/pollen association is broadly similar to that in the Woolwich Shell Beds. It is distinguished by the presence of consistent Spinizonocolpites spp. and Dicolpopollis luteticus.

5. In each association certain spore/pollen species are distinguished as coming from local or distant sources. The depositional sites are discussed in terms of proximity to the source vegetation, thus local, distant and intermediate sites are recognised.

6. There are very few stratigraphically restricted species and these are rare. Those which occur in the Thanet Beds ± the Woolwich and Reading Beds are Trudopollis hammenii, Stephanoporopollenites hexaradiatus subsp. Vacuopollis semiconcavus and Pentaporoites belgicus. A second group appears at the top of the London Clay and in the basal Bracklesham Beds. The most significant of these is Spinizonocolpites spp. which is consistent in the base of the Bracklesham Beds.

7. The assemblages of dinoflagellate cysts, acritarchs and other algae recorded here conform with published zonal schemes, established for the early Tertiary in the rest of Europe and the North Sea. The following zones are recognised:-

(a) The Thanet Beds are within the Deflandrea speciosa Zone of Caro (1973) and the Alisocysta margarita informal zone of Knox et al. (1981).

(b) The Apectodinium hyperacanthum Zone is recognised in the Woolwich and Reading Beds, from the upper part of the Woolwich Bottom Bed into the Striped Loams and also in the base of the Oldhaven Beds.

(c) Assemblages from the London Clay correspond to the Micrhystridium association of Downie et al. (1971). Only one of the Wetzelliacea zones of Costa & Downie (1976) has been distinguished, the Dracodinium similis zone within King's (1981) Division B2 at Alum Bay.

8. Thus the new data obtained during the present investigation confirm the similarity between late Palaeocene and early Eocene microfloras from southern England and adjacent areas on the Continent, particularly France, Belgium and Germany and show certain similarities with microfloras from eastern and southeastern U.S.A.

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INDEX TO TAXA DISCUSSED IN CHAPTER 4.

This is not intended to be a complete list of the species recorded above, only those discussed in the systematic section (Chapter 4) are included.

MICROPLANKTON.

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Alisocysta margarita, p.180, pl.18, fig.3,4.
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Apectodinium hyperacanthum, p.181, pl.19, fig.1.
Apectodinium parvum, p.182, pl.19, fig.2,3.
Apectodinium quinquelatum, p.183, pl.19, fig.6.
Areoligera sp. p.184, pl.19, fig.12,13.
Areoligera senonensis, p.184, pl.19, fig.4,9,11.
Baltisphaeridium sp. B. p.198, pl.24, fig.2,3.
"Cleistosphaeridium" group p.184, pl.19, fig.5,7.
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Deflandrea dartmooria/oebisfeldensis, p.185, pl,20, fig.2,3,5-7,11.
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?Trichodinium sp. p.194, pl.23, fig.8,13,14.

Trigonopyxidia ginella, p.200, pl.24, fig.7.
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Wetzeliella lunaris, p.198, pl.28, fig.19.

PLATES

The location of each specimen is given either as an England Finder reference or as the vernier reading from Paleoservices' Leitz Microscope No.1.

PLATE 1

All figures x1000 unless otherwise indicated.

Fig.

1 Hydrosporis levis Krutzsch 1962. Microspore within microspore massula, JL865A(2);EF:Q14.

2 Hydrosporis levis Krutzsch 1962. Detail from fig.4, microspores within massula, JL865A(4);EF:H47/3.

3 Triplanosporites sinuosus (Pf.) Thomson & Pflug 1953. PK6b;EF:D29/4 x500.

4 Azolla/Salvinia microspore massula, JL865A(4), single mount x200.

5 Leiotriletes sp. PK6/10, single spore mount.

6 Polypodiaceoisporites sp. cf. P. marxheimansis (Murr." & Pf. 1952 ex Th. & Pf. 1953) Krutzsch 1959b. PK21D(2);EF:U37/4.

7 ?Tegumentisporis sp. PK21D(3);EF:K31.

8 ?Tegumentisporis sp. PK4b;EF:C53.

9 Polypodiaceoisporites marxheimensis (Murr." & Pf. 1952 ex Th.& Pf. 1953) Krutzsch 1959b. JL865b;448972 x500.

10 Leiotriletes sp. JL865b;385107[1].

11 ?Tegumentisporis sp. SL10/19, single spore mount.

12 ?Tegumentisporis sp. PK6/20, single spore mount.

13 Polypodiaceoisporites sp. cf. P. marxheimensis (Murr" & Pf. 1952 ex Th. & Pf. 1953) Krutzsch 1959b. JL867a;282948 x500.

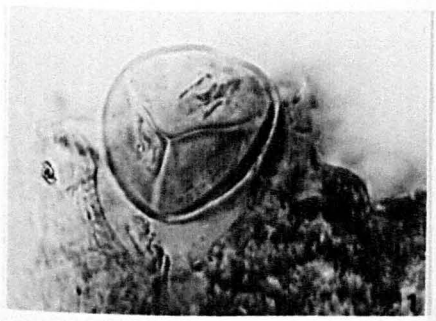
14 Cicatricosisporites dorogensis Pot. & Gell. 1933. JL898a;EF:L46 x500.

15 Cicatricosisporites paradorogensis Krutzsch 1959. JL898a;EF:O32/2 x500.

16 Polypodiaceoisporites macrospeciosus (R.Pot.& Gell. 1933) Pot.1956 PK6/9, single spore mount.

17,18 Densoisporites velatus Wey.& Krieger 1953. A49/2; 357108[1]. 17 Proximal face, 18 optical section.

19 Kraeuselisporites reissingeri (Harris 1957) Morbey 1975. OG27(4);355100[4].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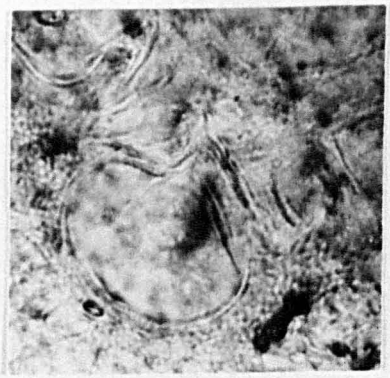

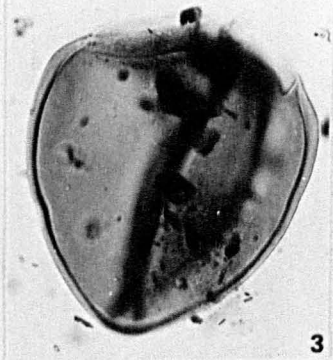
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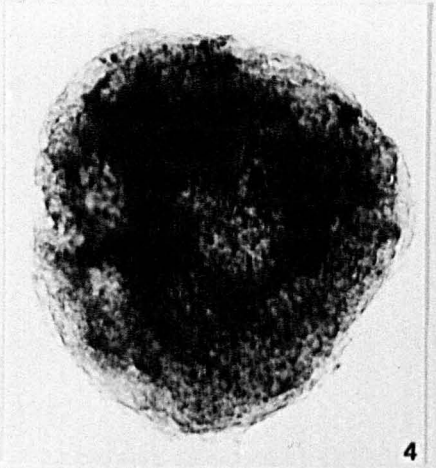
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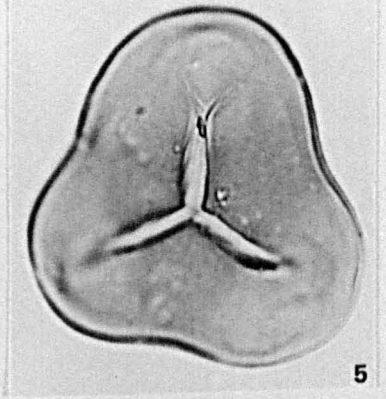
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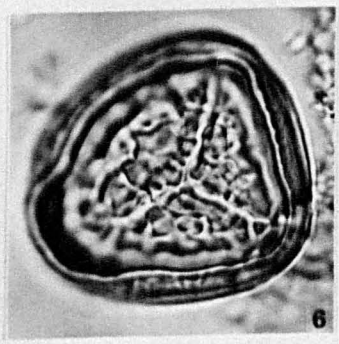
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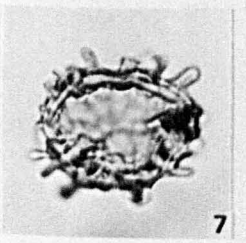
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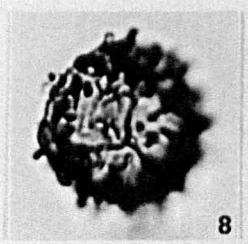
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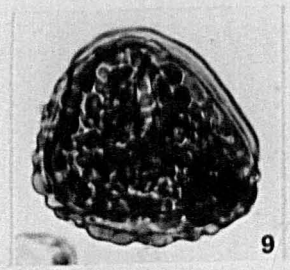
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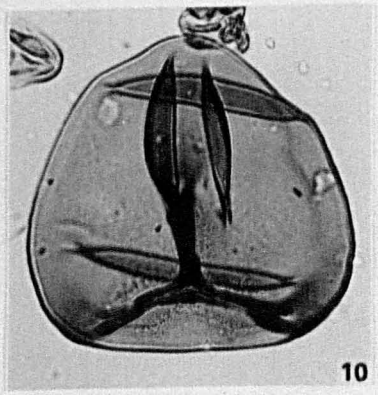
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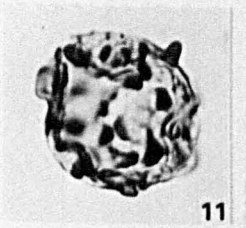
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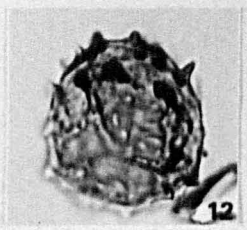
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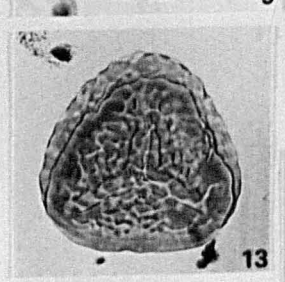
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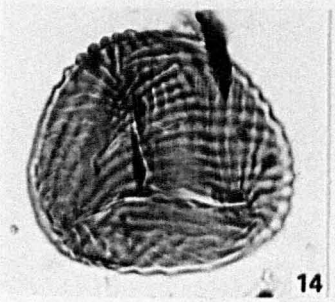
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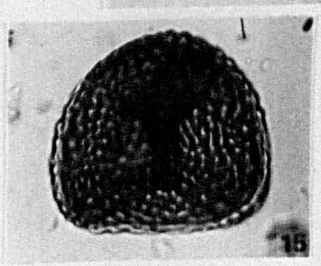
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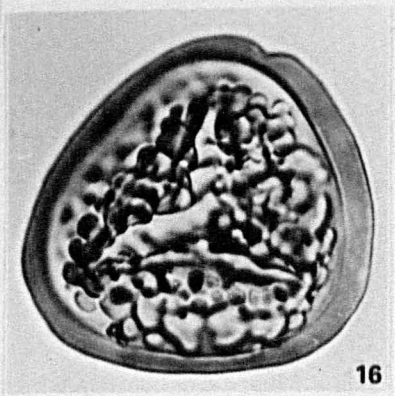
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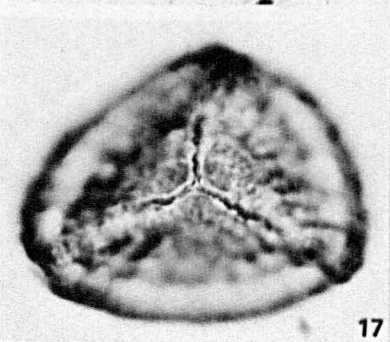
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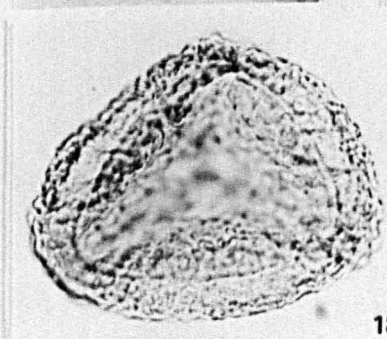
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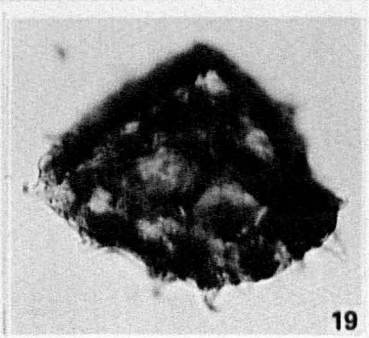
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PLATE 2

All figures x1000 unless otherwise indicated.

Fig.

1 Laevigatosporites discordatus Pflug 1953. JL865b; 2901092.

2 Ornamented monolete spore, JL898c;EF:D29/3.

3 Laevigatosporites haardti (R.Pot.& Venitz 1934) Th.& Pf. 1953.JL864b;350990.

4 Cerebropollenites mesozoicus (Couper 1958) Nilsson 1958.PK4/1;EF:037/3 x500.

5 Callialasporites dampieri (Balme) Suk Dev 1961. OG27(4);245990 x500.

6 Bisaccate pollen, undifferentiated,JL867c;4121108.

7 Bisaccate pollen, undifferentiated,PK4/2;EF:T42 /1 x500.

8 Quadraeculina anellaeformis Maljavkina 1949 sensu Schulz 1967. PK20D(1);EF:M34.

9 Taeniaesporites sp. cf. T. noviaulensis Leschik 1955. x c.900 CH18c(2);395925.

10 Vitreisporites pallidus (Reissinger) Nilsson 1958. LR17b;320985.

11 Florinites sp. OG7D(4);2321060 x500.

12 Chasmatosporites sp. OG27(4);4531105.

13 Inaperturopollenites polyformosus (Thiergart) Pf.& Th. 1953.OG27/(4);364955.

14 Inaperturopollenites polyformosus (Thiergart) Pf.& Th.1953.PK21D(2);EF:G47/2.

15 Classopollis torosus (Reissinger) Balme 1957.PK56; EF:Q30/3.

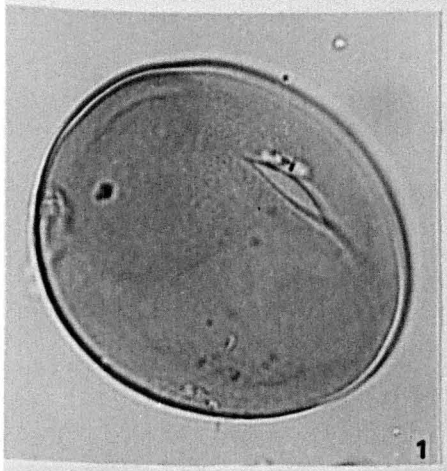
16 Spheripollenites scabratus Couper 1958.PK21D(3); EF:K45/2.

17 Spheripollenites scabratus Couper 1958.OG1C(2); 4281091.

18 Inaperturopollenites hiatus (Potonie) Pf.& Th. 1953. PK4/1;405985.

19 Rhaetipollis germanicus Schulz 1967.LR17/1;4611091.

PLATE 2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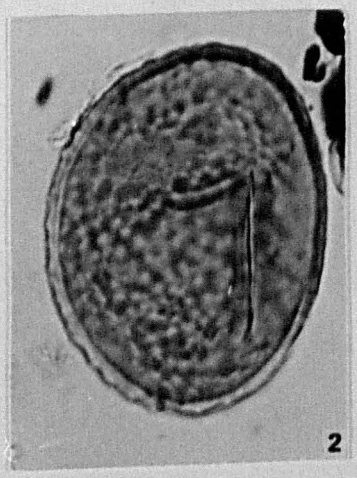
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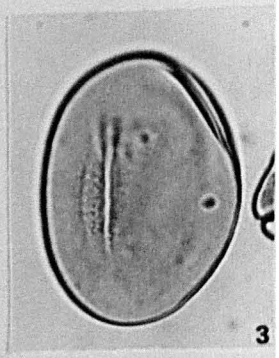
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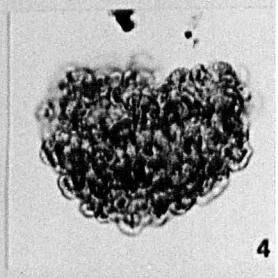
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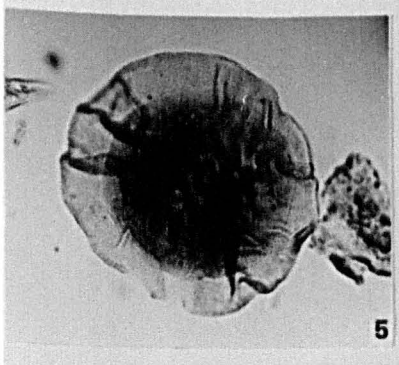
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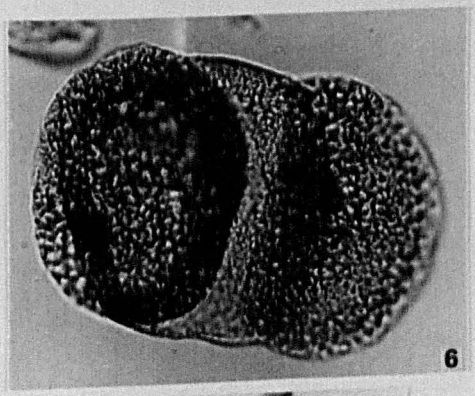
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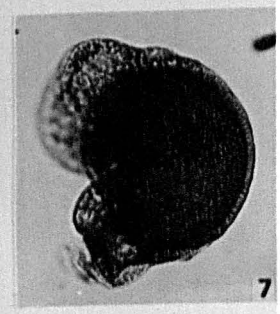
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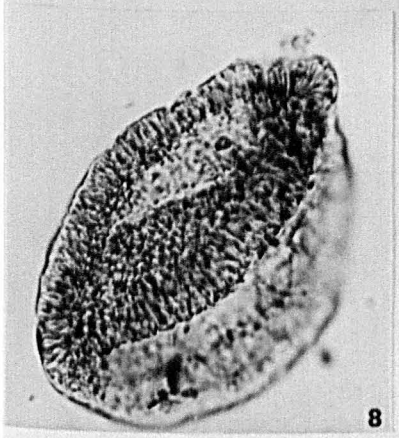
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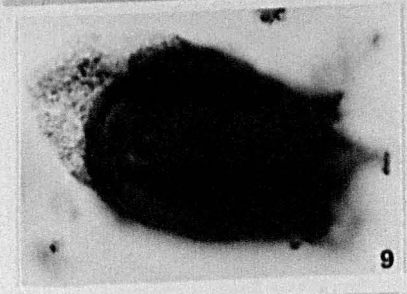
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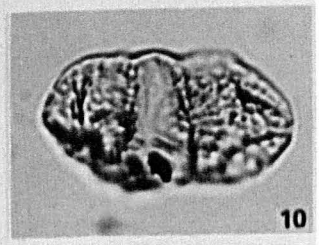
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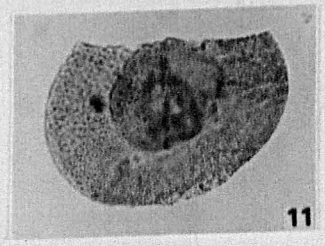
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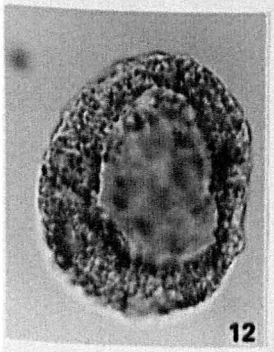
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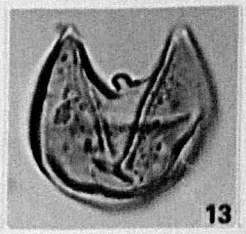
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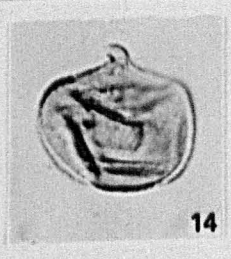
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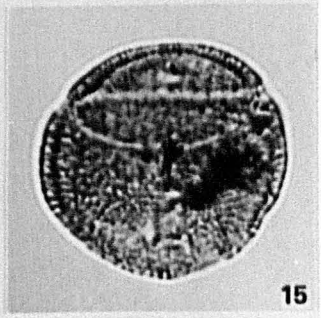
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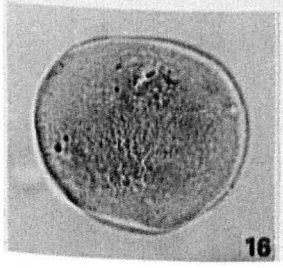
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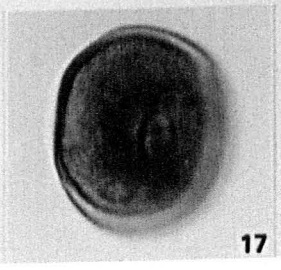
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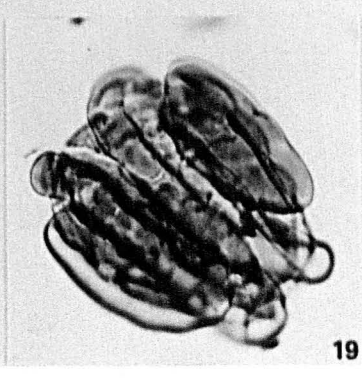
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PLATE 3

All figures x1000 unless otherwise indicated.

Fig.

1 Milfordia incerta (Th.& Pf.) Krutzsch 1961d. JL865b; 2651072.

2 Spinizonocolpites echinatus Muller 1968. AB57(2); 265935.

3 S. echinatus Muller 1968. AB60(3);2911008.

4,5 Clavatipollenites sp. AB57(2);298912.

6 Liliacidites sp. AB57(2);3451082.

7,8 Clavatipollenites sp. OG12(2);340919.

9-13 Monocolpopollenites tranquillus (Pot.) Th.& Pf.1953. 9 AB60(3);4601031. 10 Cluster of several specimens, JL865b;401911 x500. 11 JL865b;EF:X35. 12 JL866b; 4191071. 13 S.E.M. Stub 81 (strew) x1000.

14,17 Dicolpopollis luteticus (Gr.-Cav. 1967b) Gr.-Cav. 1976d. AB60(2);3821059.

15,16 Cupuliferoidaepollenites spp. (liblarensis/micro-henrici group) PB8a;515975.

18,19 Dicolpopollis aff. luteticus, JL865c;3311082.

20-22 Cupuliferoidaepollenites spp. (liblarensis/micro-henrici group). 20. AB60/3;3211009. 21 JL867b; 2521122. 22 JL867b;2581118.

23 Ovalipollis ovalis Krutzsch 1955 emend. Klaus 1960. PK21D(2);2631002.

PLATE 3

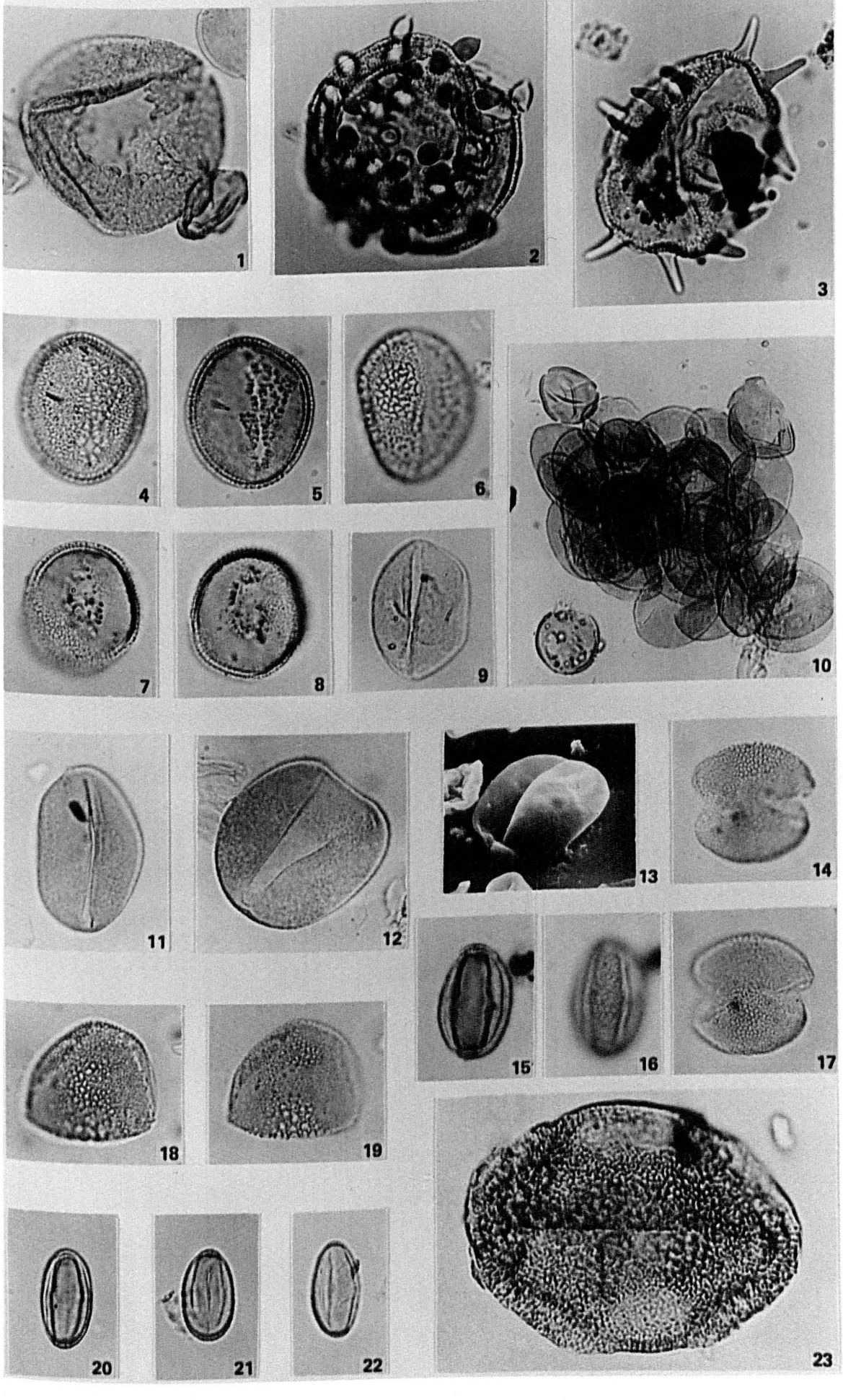


PLATE 4

All figures x1000 unless otherwise indicated.

Fig.

1,2 Cupuliferoidaepollenites cf. liblarensis Th.1950 ex Pot. 1960. 1 JL898/3; EF:W40 x1500. 2 JL867a; EF:G33/3 x1500.

3-6 Margocolporites cf. lihokus Srivastava 1972. 3 PK5c;EF:S43/2. 4 PK5d;EF:R36/2. 5,6 LR14/2; 3041112.

7 Nyssapollenites sp. B. sp. nov. PK6/31, single spore mount.

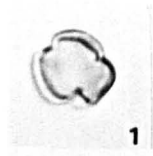
8-11 Nyssapollenites sp. A. sp. nov. 8,9 PK4/5, single spore mount, specimens from a cluster. 10 S.E.M. of part of a cluster, x1000. Stub 85c, specimens later mounted in glycerine jelly, S85x. 11 Same specimen, detail of aperture. S.E.M. x3000.

12,13 Nyssapollenites sp. PK21D(2);EF:R37.

16 Nyssapollenites sp. PK20a;EF:G45/1.

14,15,17-22 Rhoipites sp. A. sp. nov. 14 PK5b;EF:P33/1, oblique orientation to show wall structure and costae which continue around the end of the colpus 15,17,18 Typical specimen, PK6b;EF:W43. 15,17 To show structure of pores and costae. 18 Reticulate ornament. 19 Polar view, PK6/34, single spore mount. 20,21 PK21d(2);EF:K39/1. 22 Cluster of pollen grains PK21D(1);EF:A31.

23-26 Rhoipites sp. B. sp. nov. 23,24 JL898c;EF:D28/1. 25,26 PK21D(2);EF:G46/4.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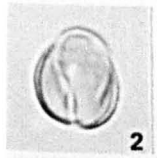
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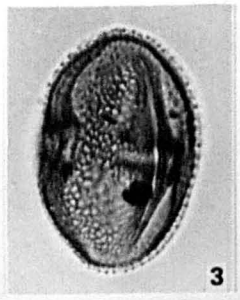
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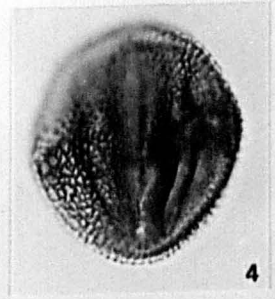
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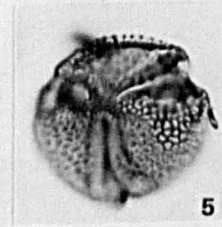
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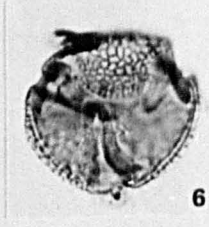
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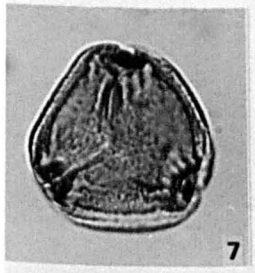
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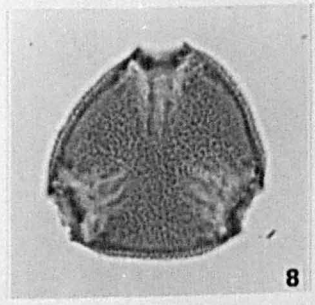
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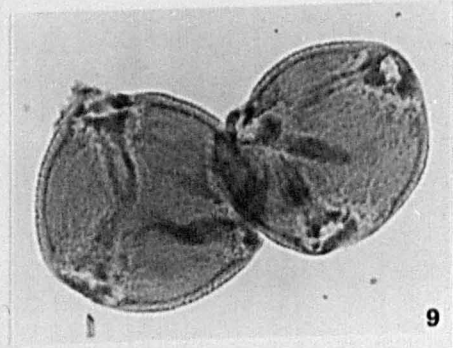
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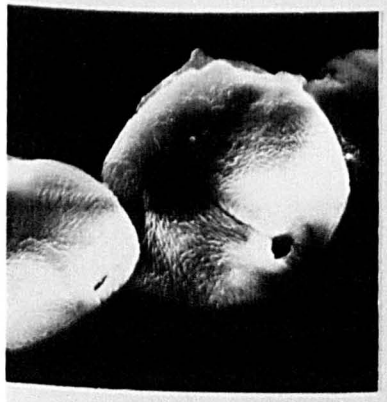
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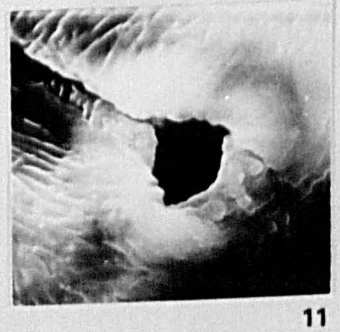
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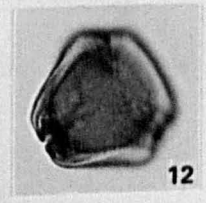
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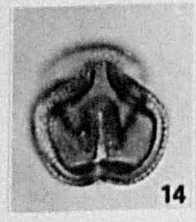
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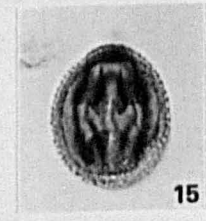
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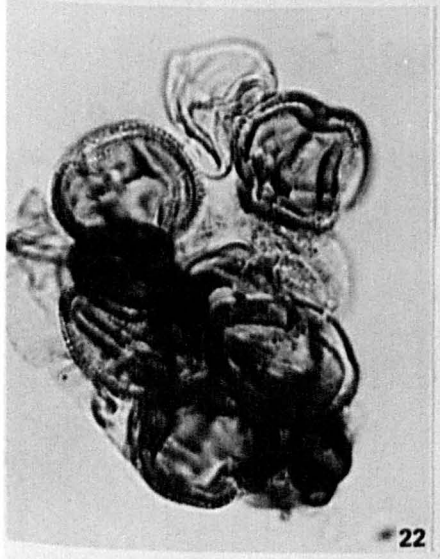
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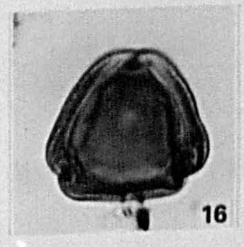
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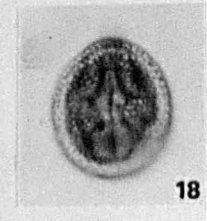
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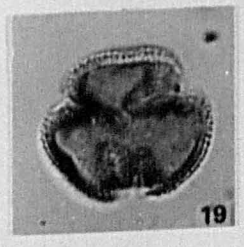
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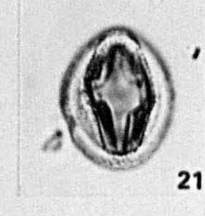
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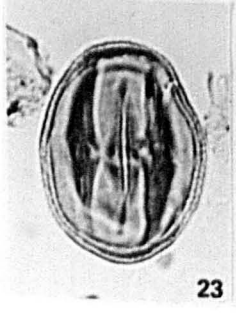
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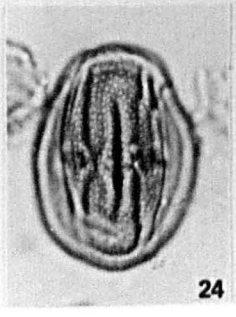
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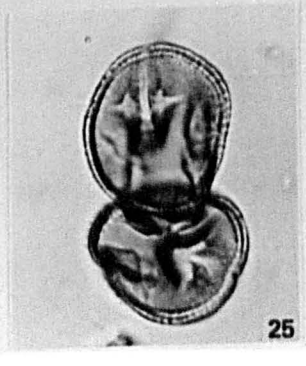
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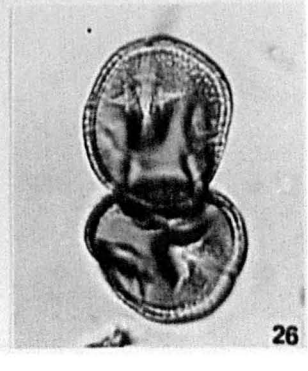
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PLATE 5

All figures x1000 unless otherwise indicated.

Fig.

1-3 Rhoipites sp. B. sp.nov. Typical specimen, NB1(4); 300963. 1,2 Costae and pore structure, 3 scrobiculate to reticulate ornament.

4 Rhoipites psinnus Stanley 1965. PK4/1;EF:031/3.

5-14 Tricolpites parvus Stanley 1965. 5 Oblique orientation, showing wall structure, PK21D(1); EF:F28/2. 6 Specimen with granular colpal membrane preserved and microreticulate ornament, 7 another focal plane, wall structure, SL9a;3851020. 8,9 Specimen with torn colpal membrane, PK21D(1); 395918. 11 PK21D(3);EF:K50/2. 12-14 PK21D(3); EF:L51. 10 PK21D(3); EF:L51/4.

15-17 Tricolpites cf. parvus Stanley 1965. OG28(4); 480942.

18-21 Tricolpites sp. A. sp. nov. 18 Part of a large cluster, JL864b;3101040 x500. 19 Detail of 2 grains from fig.18, x1250. 20,21 Typical specimen JL867b;250962. 20 Reticulate ornament on the mesocolpium, 21 smooth margines adjacent to the colpus.

22-24 Tricolpites sp. B. sp. nov. 22,23 Typical specimen, JL865c;328982. 22 Scrobiculate ornament, 23 wall structure, granular to microreticulate structure. 24 Another specimen, oblique orientation showing ragged edges to the colpi, JL866c;280922.

25 Tricolporopollenites cingulum (Pot.) Pf.& Th.1953. LR14/1;397952.

26-28 Tricolpites sp. C. sp. nov. 26,27 Typical specimen, showing details of the colpal membranes and the reticulate ornament, PK21D(2);EF:L47/2. 28 Specimen with finer reticulate ornament, PK21D(2); EF:U42.

29 Tricolporopollenites cingulum (Pot.) Pf.&Th. 1953. JL887/1;461970.

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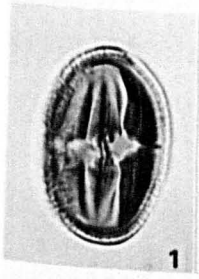
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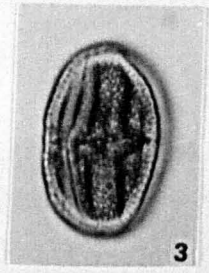
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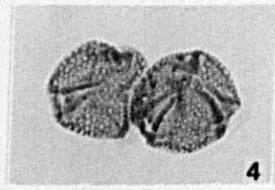
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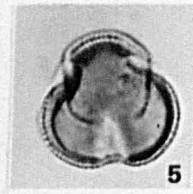
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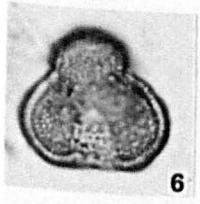
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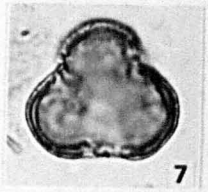
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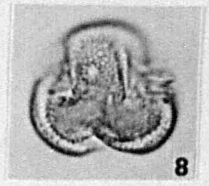
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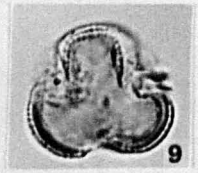
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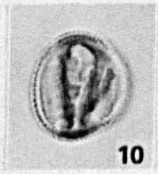
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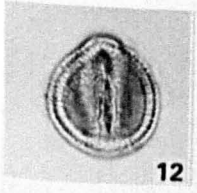
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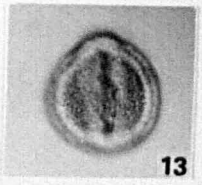
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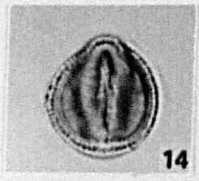
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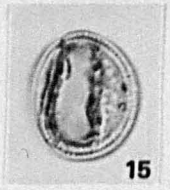
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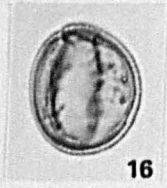
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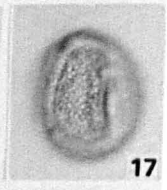
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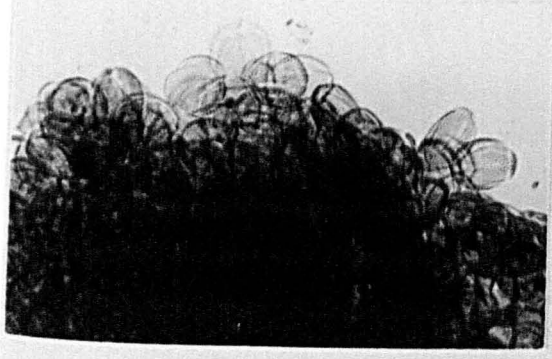
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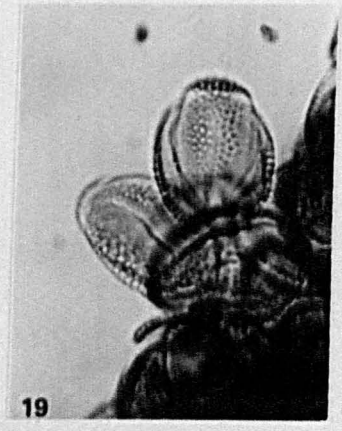
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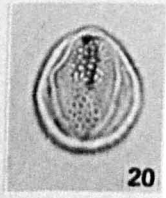
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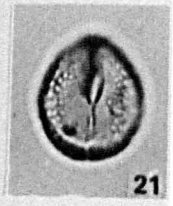
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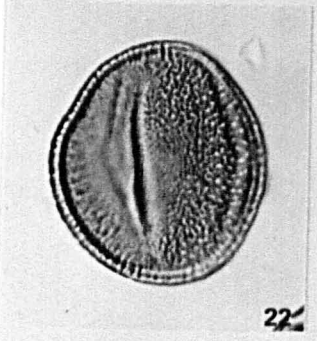
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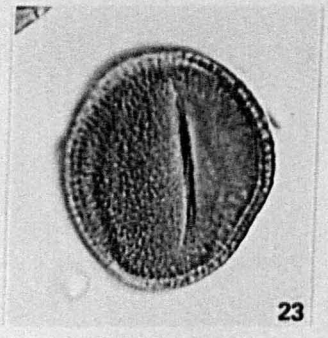
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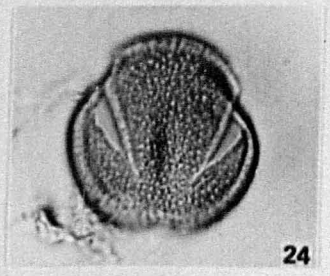
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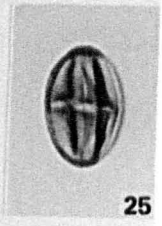
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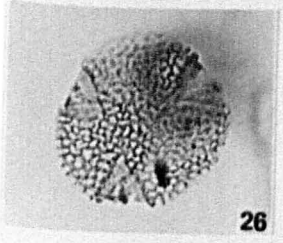
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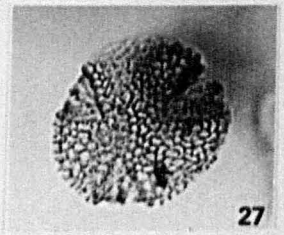
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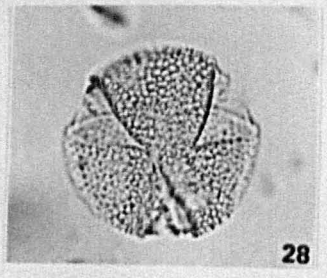
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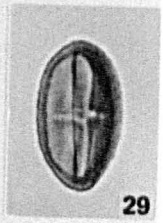
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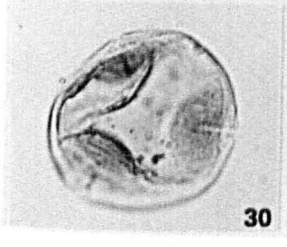
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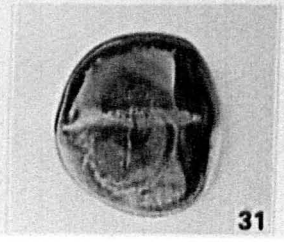
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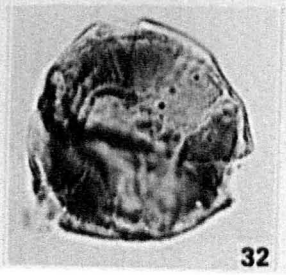
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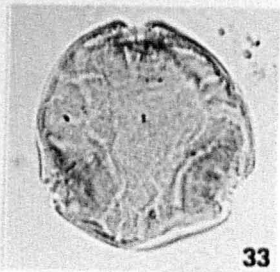
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PLATE 5 continued

Fig.

30-33 Tricolporopollenites mansfeldensis Krutzsch 1969a. 30 Very broad endexinous thickenings (costae) adjacent to the colpi, OG5(3);333935. 31 Equatorial view showing broad costae interrupted by equatorially elongated rugae, NB1(4);408913. 32 Polar view, NB1(4);477931. 33 Polar view showing endexinal grooves, possibly a preservational feature, NB1(4);478926.

PLATE 6

All figures x1000 unless otherwise indicated.

Fig.

1-3 Tricolporopollenites mansfeldensis Krutzsch 1969a. 1,2 Oblique specimen with four apertures, showing broad costae interrupted by equatorially elongated rugae, NB1(3);482934. 3 NB1(8);4131048.

4-7 Tricolporopollenites megareticulus Krutzsch & Vanhoorne 1977. 4 Polar view showing separation of the reticulate ektexine from smooth endexine, JL898a;EF:026/1. 5 JL885b;380982. 6,7 JL898/3; EF:W47/4.

8-12 Tricolporopollenites duplibaculatus Gr.-Cav. 1966. 8 Mid-focus showing costae and wall structure, SL10/7, single spore mount. 9,10 PK6/4, single spore mount. 9 Costae and wall structure, 10 reticulate ornament. 11 JL865c;specimen lost. 12 SL10a;412981.

13,14 Tricolporopollenites aceroides (Pot.) Pf.& Th. 1953. 13 S.E.M. showing striate ornament x1000. Stub S81 (strew mount). 14 JL898a;EF:S27.

15 Tricolporopollenites margaritatus (Pot.) Th.& Pf. 1953. PK21D(2);EF:047/4.

16 Tricolporopollenites iliacus (Pot.) Pf.& Th. 1953. JL887/1;454982.

17-19 Aesculiidites circumstriatus (Fairchild) Elsik 1968. 17 Polar view showing striae concentric about the pole, LR14/1;3711078. 18,19 Equatorial view, 18 ornament, 19 mid-focus, JL905a;specimen lost.

20-21 Tricolporopollenites megaexactus (Pot.) Th.& Pf. 1953 subsp. exactus. 20 PK5c;EF:N50. 21 PK4/3; EF:036/4.

22,23 Tricolporopollenites kruschi (Pot.) Th.& Pf. 1953. 22 JL887c;272942. 23 SL9a;2901067.

24 Tricolporopollenites cf. sittlerii Roche 1973.

25 JL887/1;428984. Striate tricolpate/tricolporate pollen, undifferentiated, JL867a;283950.

PLATE 6

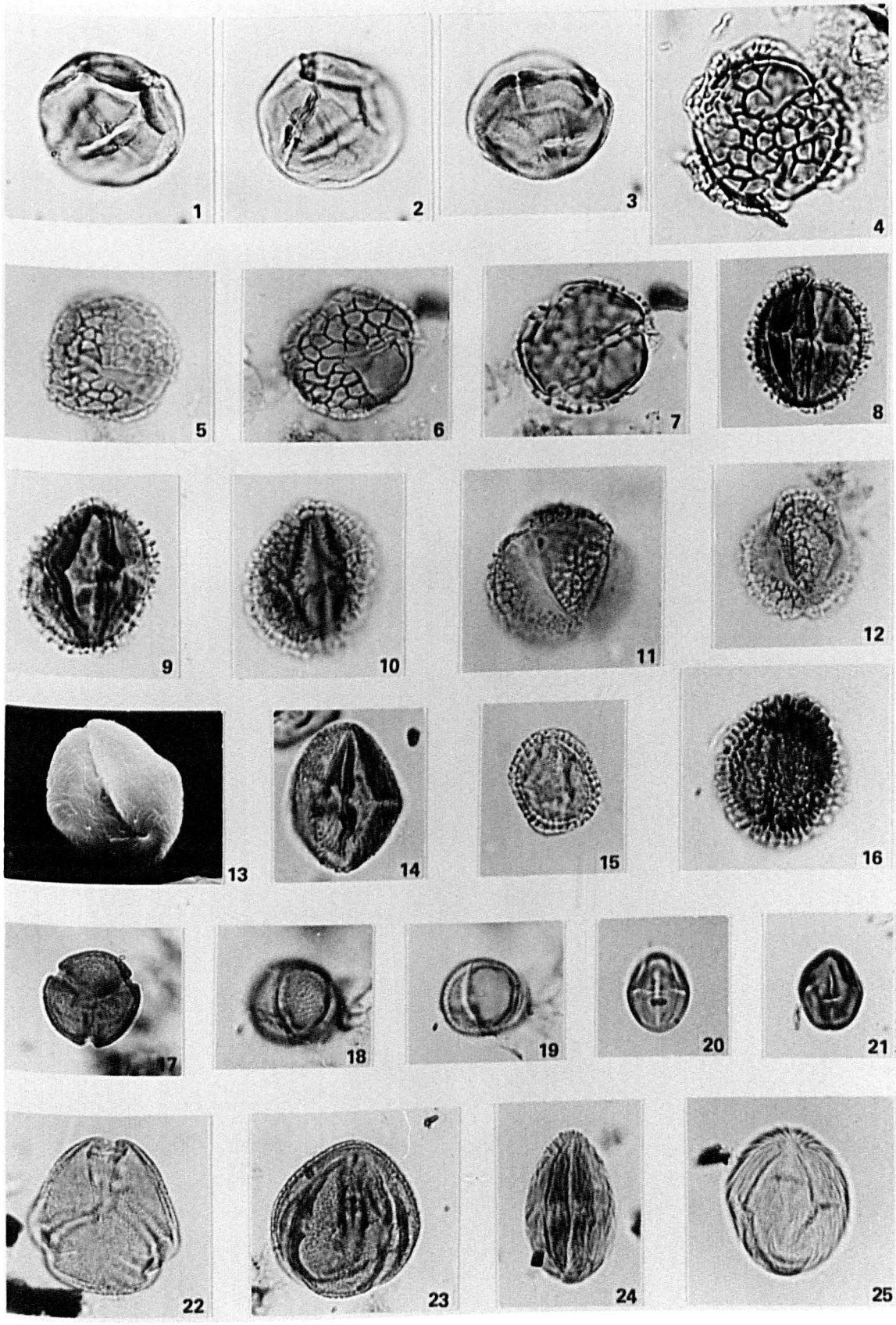


PLATE 7

All figures x1000 unless otherwise indicated.

Fig.

1,2,5 Tricolporopollenites sp. A. AB60(2);311987.

3,4 Fraxinopollis variabilis Stanley 1965.
3 SL9a;4451075. 4 SL10/11, single spore mount.

6,8-10 Cornaceoipollenites parmularius (Pot.) Potonié 1960.
6 JL865a;3521008. 8 S.E.M. oblique polar view showing scabrate ornament x1000. Stub S81 (strew mount). 9 JL865b;265973. 10 Equatorial view with ?weak costae or folded colpal membrane, JL865a;428982.

7 ?Faguspollenites sp. AB64(2);405961.

11 Favitricolporites baculoferus (Pflug) Srivastava 1972. JL898a;EF:E38.

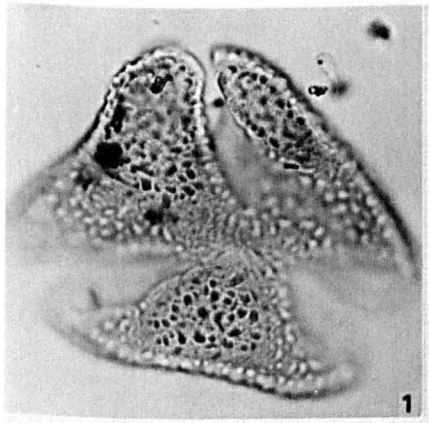
12 Duplopollis golzowense Krutzsch 1961d. OG7(2); 3371040.

13 Cupanieidites encalyptoides Krutzsch 1962a. JL898/3;EF:W40/4.

14-16 ?Cyrillaceaepollenites spp., undifferentiated.
14 AB57(2);4081092. 15 AB57(2);3281008.
16 WKc/1;EF:J39/4.

17 cf. Favitricolporites baculoferus (Pflug) Srivastava 1972. Part of a cluster, tricolporate pollen with weak costae, NB1(4);4411088.

18,19 ?Brevicolporites sp. 18 AB57(2);3231052.
19 AB60(3);450915.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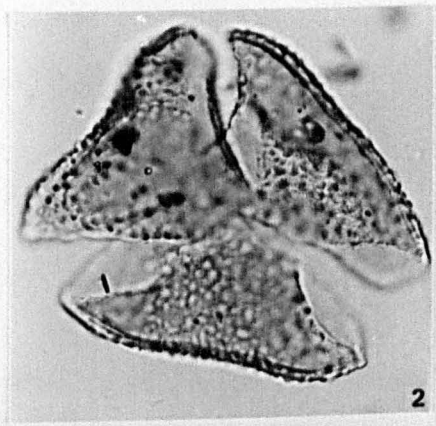
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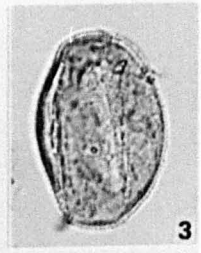
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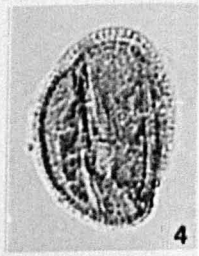
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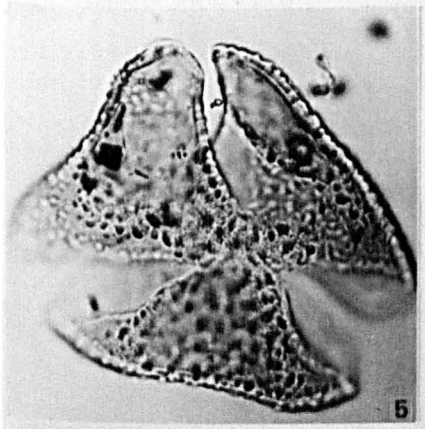
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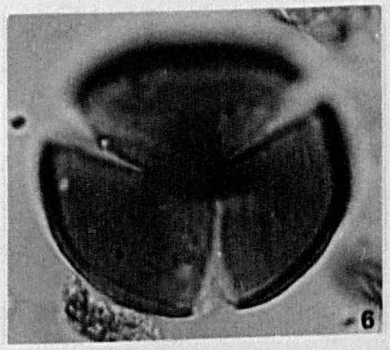
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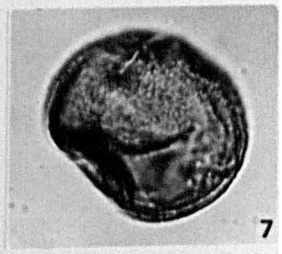
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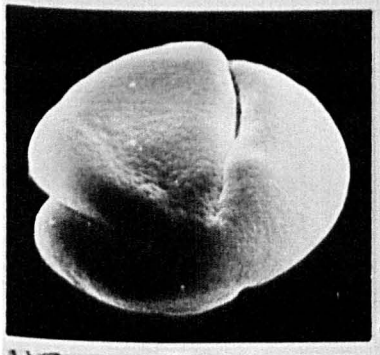
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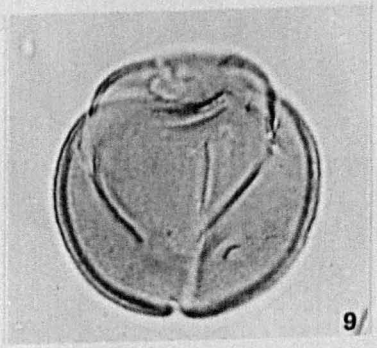
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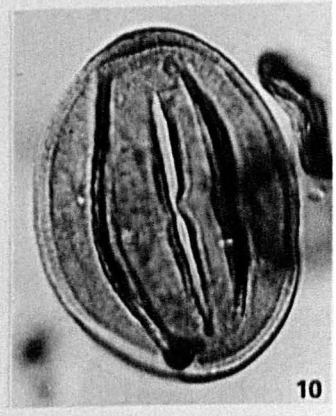
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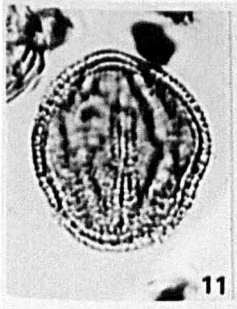
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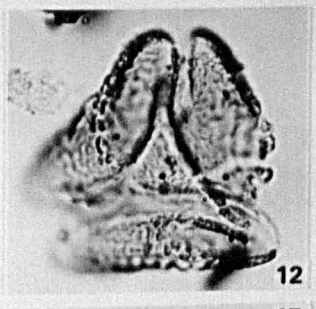
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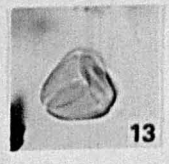
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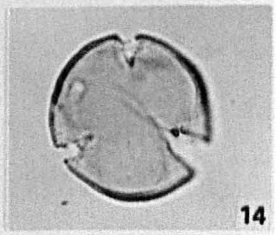
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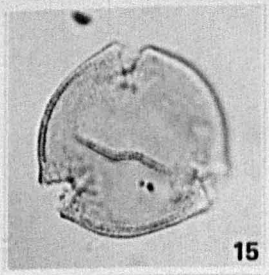
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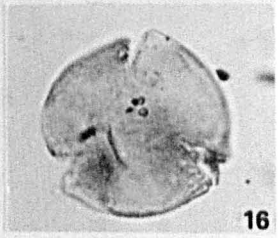
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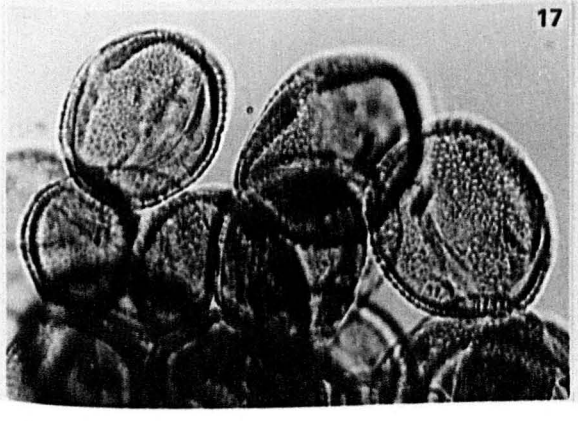
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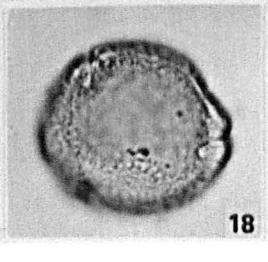
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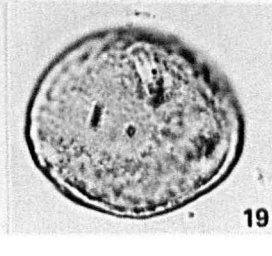
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PLATE 8

All figures x1000 unless otherwise indicated.

Fig.

1,2,3 Fraxinopollenites variabilis Stanley 1965. 1,2 PK21D(3);EF:K51/3. 3 OG28(4);350l062.

4,5 cf. Fraxinopollenites variabilis. OG28(4);4521070.

6-10 Pentapollenites spp. 6,7 PK20D(1);416970. 8,9 AB57(2);293958. 10 AB57(2);308960.

11-13,17 Retitrescolpites anguloluminosus (Anderson 1960) Frederiksen 1979. 11,12 Oblique polar view, PK4/1;EF:G50. 13,17 Equatorial view, JL898a; EF:E42/1.

14 ?Spinulaepollis sp. 14 JL864;3221052.

15,16 Spinaepollis spinosus (R.Pot. 1931) Krutzsch 1961(d). JL898a;EF:P47.

18,19 ?Spinulaepollis sp. 18 PK35A/2;4351045. 19 WKc/1;EF:H35/1.

20-26 Polycolpites sp. A. sp. nov. 20-22 Oblique equatorial view OG12(1);EF:U42/9. 21 Mid-focus showing pilate exine. 22 Two of the colpi on the opposite surface. 23,24 Typical specimen, PK21D(3);EF:V32/1. 23 Mid-focus, 24 showing two short colpi and granular exine. 25,26 Another specimen, equatorial view, OG12(2);EF:S35. 25 Showing two colpi and exine with closely spaced delicate pila. 26 Opposite surface with reticulate to granular exine pattern.

27 Tetracolporopollenites sp. JL898a;EF:X34/2.

28 Tetracolporopollenites manifestus (R.Pot.) Th.& Pf. 1953. AB68(3);460938.

29,30 Tetracolporopollenites sp. 29 NB1(4);456924. 30 PK4/3;EF:R48/3.

31 Tricolpate pollen, undifferentiated. PK23c;EF:N36/1.

PLATE 8

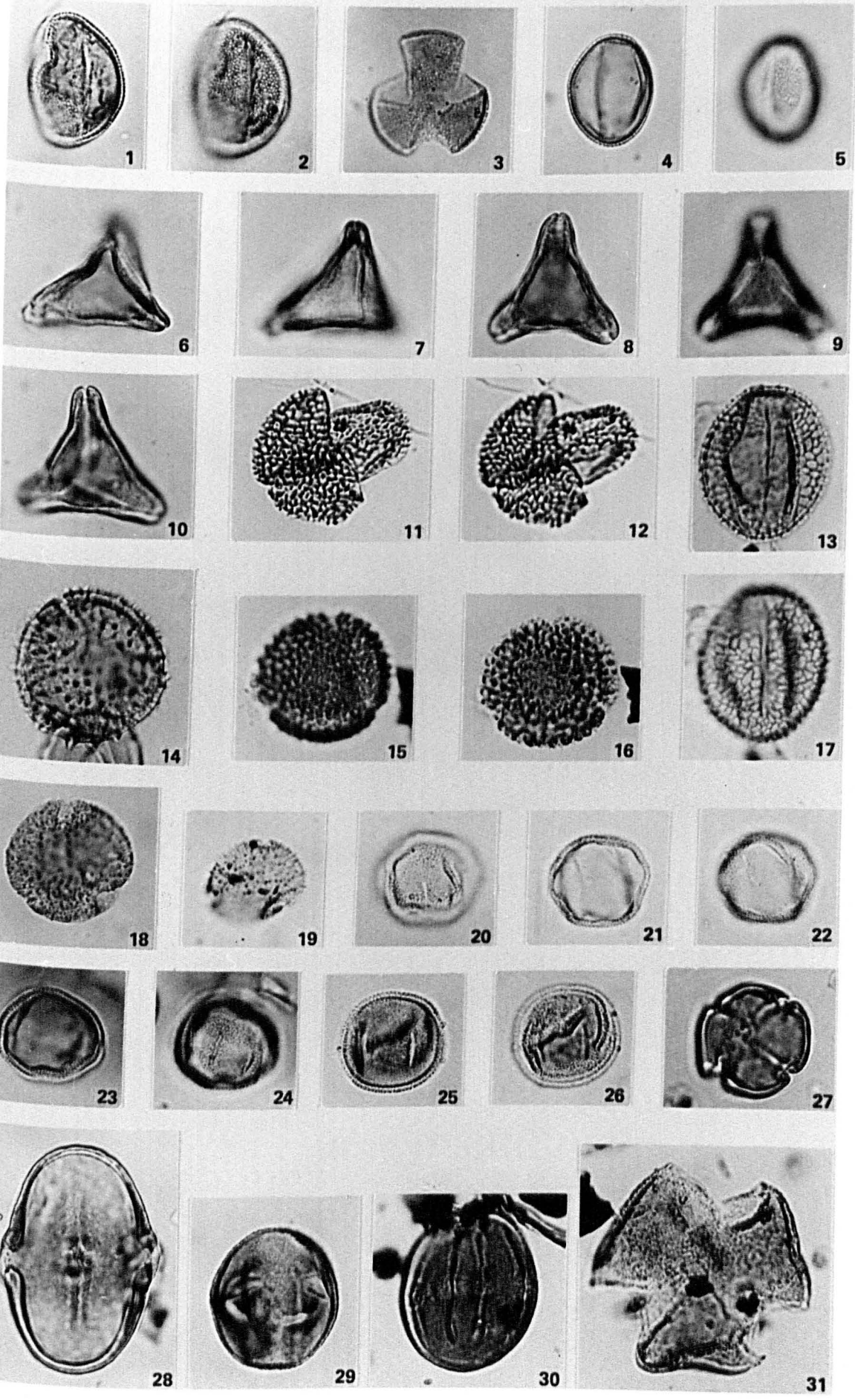
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PLATE 9

All figures x1000 unless otherwise indicated.

Fig.

1-4 Pandaniidites texus Elsik 1968. 1 S.E.M. showing spinose ornament. Aperture not visible, x1500. Specimen later mounted in glycerine jelly, S84c;EF:P38/3. 2 Folded specimen showing monoporate aperture, JL866c;3181092. 3 JL866b; 3001070. 4 JL866c;2991085.

5 Restioniidites hungaricus (Kedves) Elsik 1968. JL865c; 2351101.

6 Restioniidites minimus (W.Kr.1970) Kedves 1974. JL898a;EF:R43.

7,9,13,16 Sparganiaceaepollenites cf. cuvillieri JL866c; 407917. 7 Reticulate ornament, with small lumina adjacent to the pore and lacunae within the muri. 9,13,16 Showing duplibaculate to multibaculate muri of the reticulum with large lumina away from the pore.

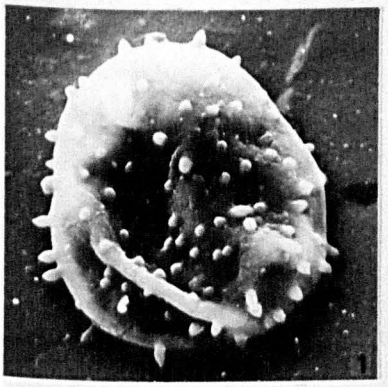
8,12,15 Sparganiaceaepollenites magnoides Krutzsch 1970a. 8 JL865b;3921120. 12 JL867c;280940. 15 JL866b; 3781029, showing variation in lumina size and simpli-duplibaculate muri.

10,11,14 Sparganiaceaepollenites cuvillieri (Gr.-Cav. 1966) Roche 1968. JL865b;2921095. 10 Wider muri adjacent to the pore, 11 thick endexine, 12 even distribution of large and small lumina.

17-19 Sparganiaceaepollenites reticulatus (Dokt.-Hrebn). W.Kr. & Vanh. 1977. 17 JL885b;268988. 18,19 JL898/2;EF:Q49. 18 Showing annulus and increase in lumina size away from the pore, 19 simplibaculate muri.

20,21 Sparganiaceaepollenites sparganioides (Meyer 1965) W.Kr. 1970c. 20 JL867b;249970. 21 JL867a; 435973.

PLATE 9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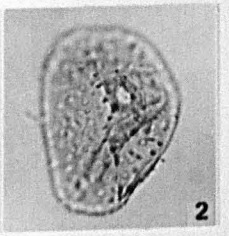
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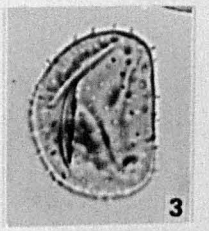
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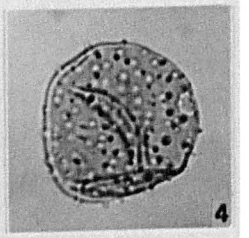
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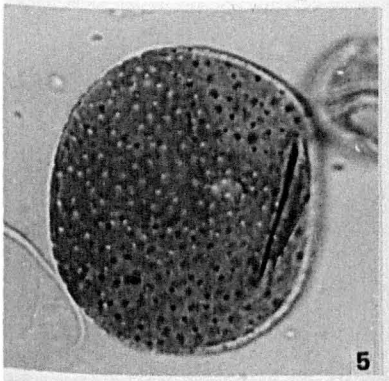
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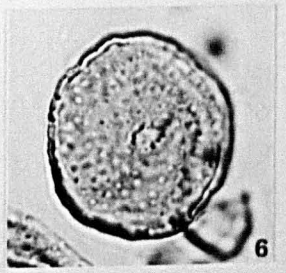
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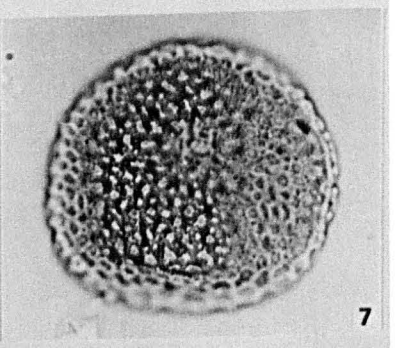
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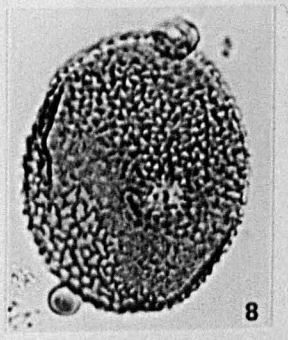
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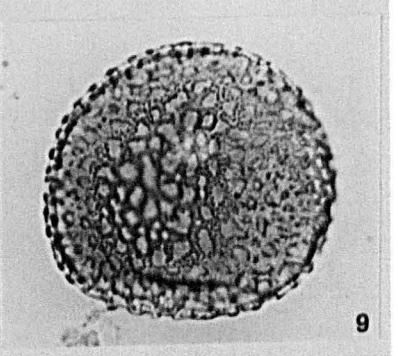
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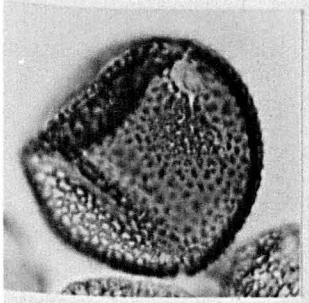
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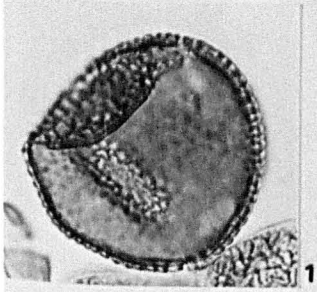
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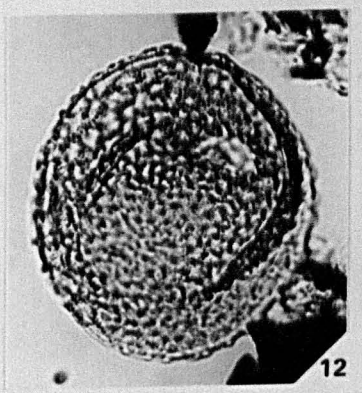
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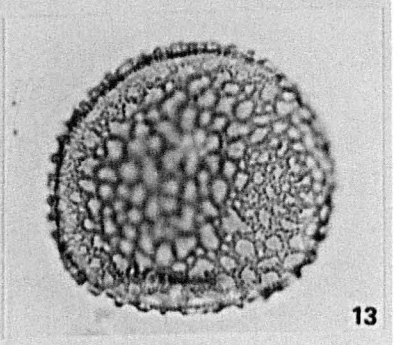
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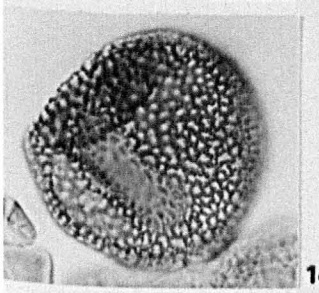
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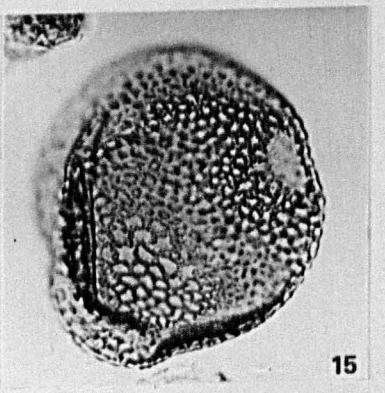
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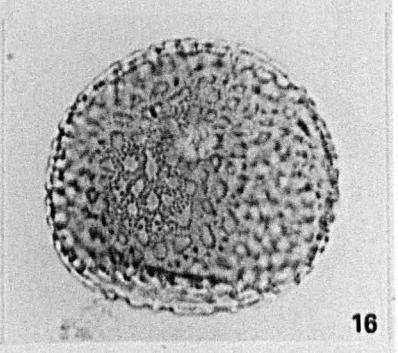
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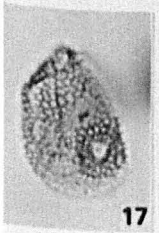
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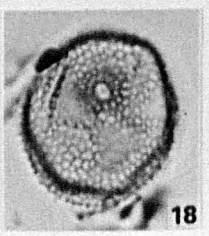
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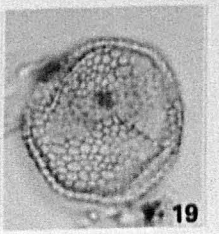
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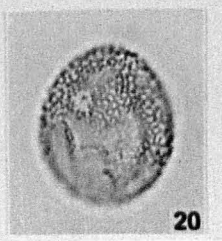
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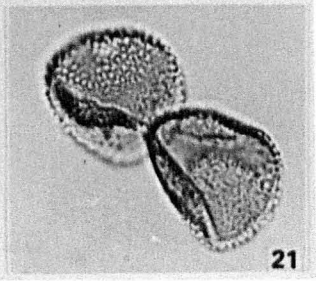
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PLATE 10

All figures x1000 unless otherwise indicated.

Fig.

1,2 Sparganiaceaepollenites sp. 1 S.E.M. of whole specimen showing reticulate ornament, x c.1300. 2 Detail of duplibaculate muri x c.3900. Specimen mounted in glycerine jelly S32b.

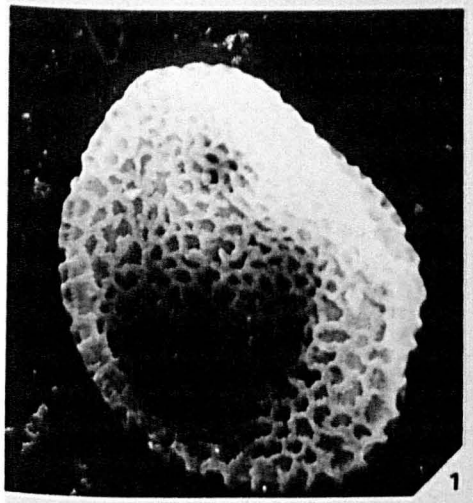
3,4,8 Sparganiaceaepollenites spp. undifferentiated. 3 JL867c;4311009. 4 JL867c;359935. 8 JL867c; 4251002.

5 Sparganiaceaepollenites sp. A. sp. nov. Typical specimen JL865b;4151125.

6 Diporites iskaszentgyorgyi Kedves 1965. AB68(3); 3921075.

7,9-11 Compositoipollenites rhizophorus (R.Pot.) R.Pot. 1960 subsp. rhizophorus. 7 SLI0a;455950. 9 Cluster of several specimens, NB2(3);4551029 x c.750. 10 Specimen showing exine structure and suprategillar spines, JL865a;3591012. 11 S.E.M. to show detail of ornament, pitted exine between the spines x4000. Stub 84a.

PLATE 10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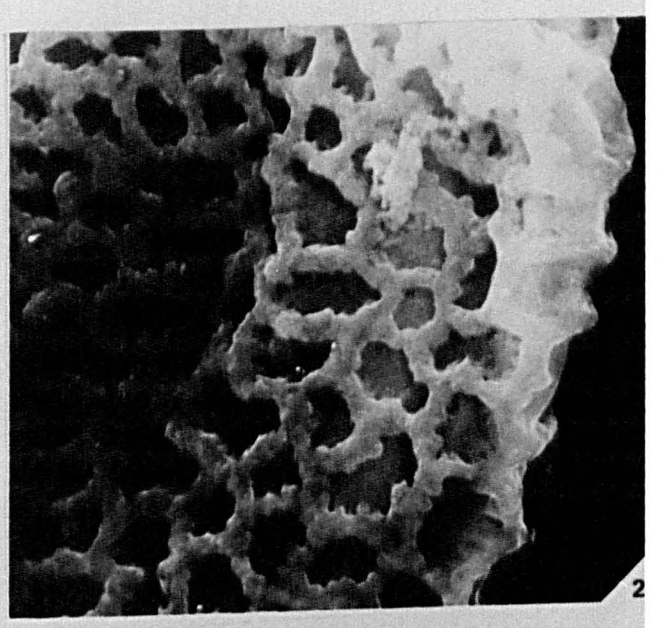
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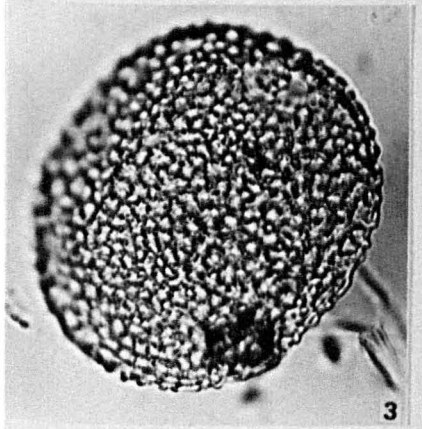
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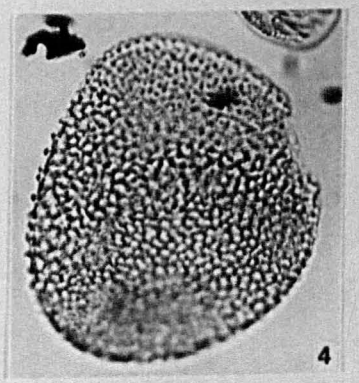
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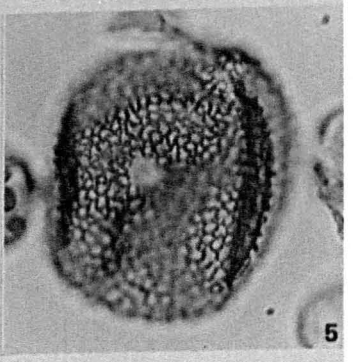
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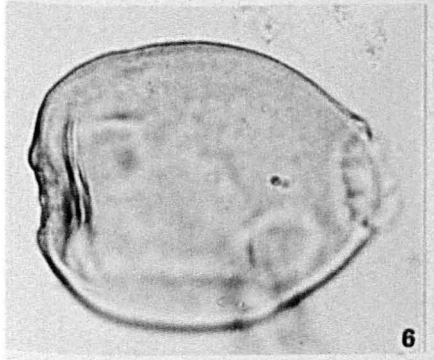
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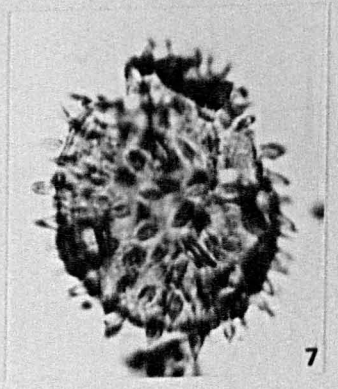
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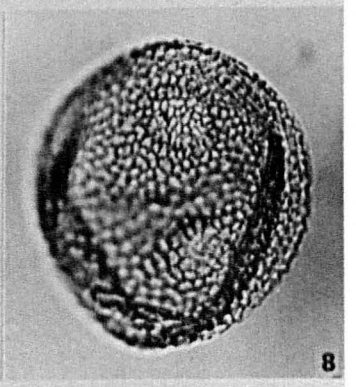
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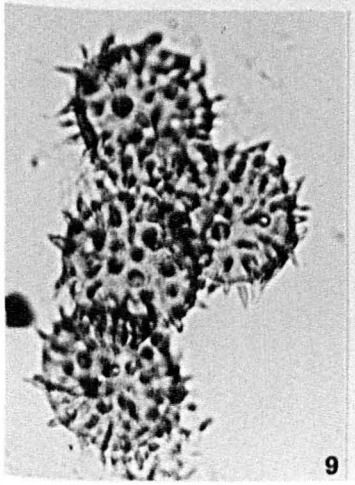
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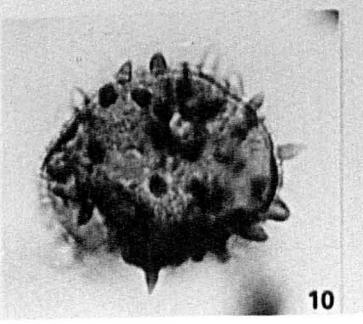
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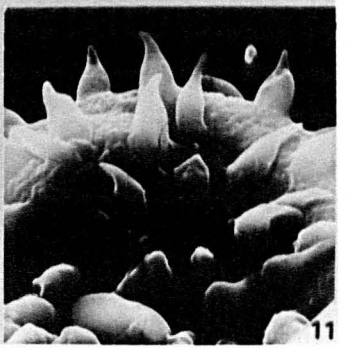
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PLATE 11

All figures x1000 unless otherwise indicated.

Fig.

1,2 Compositoipollenites rhizophorus (R.Pot.) R.Pot. 1960 subsp. burghasungensis. 1 JL866a;3551088. 2 PK20D(1);EF:G36/2.

3 Compositoipollenites rhizophorus (R.Pot.) R.Pot. 1960 subsp. minimus JL934/2d;418962.

4,5,9,10 ?Compositoipollenites sp. 4 AB57(2);3301128. 5 AB57(2);4071115. 9,10 JL898a;EF:N46/3.

6,7 Intratriporopollenites microreticulatus Mai 1961. LR14/2;3201090.

8,11-14 Intratriporopollenites pseudinstructus Mai 1961. 8 LR17a;327992. 11 PK4b;EF:H34/1. 12 Whole specimen, S.E.M. showing very short colpi and reticulate ornament x1000 (specimen lost). 13 S.E.M.,detail of aperture, x3000. 14 LR17b; 290911.

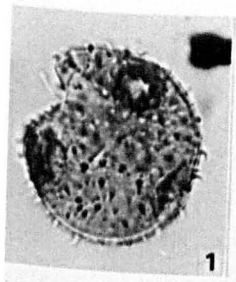
15,16,18,19 Intratriporopollenites sp. A. sp. nov. 15,16,18 Typical specimen JL865a;401990. 15 Fine reticulate ornament on one surface, 16,18 coarser reticulation on opposite surface. 19 PK4/1;EF:C 39/2.

17 Intratriporopollenites sp. JL867c;3721048.

20,21 Momipites coryloides Wodehouse 1933. 20 SL27/2; 3881065. 21 PK21D(2);EF:V47/3.

22,23 Maceopolipollenites rotundus Leffingwell 1971. 22 PK20D(1);EF:G36/4. 23 PK20D(1);EF:H34/4.

PLATE 11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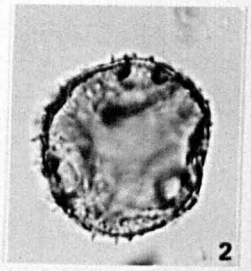
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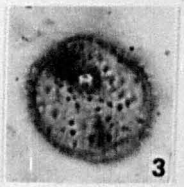
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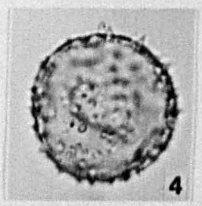
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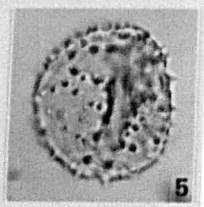
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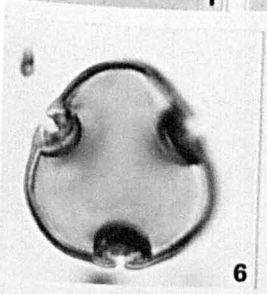
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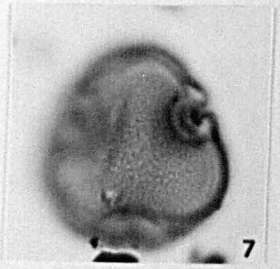
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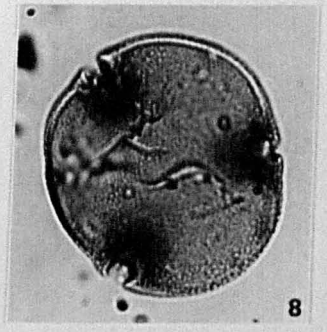
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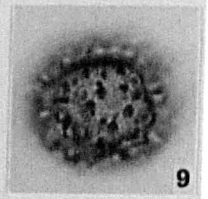
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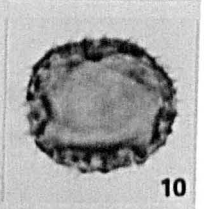
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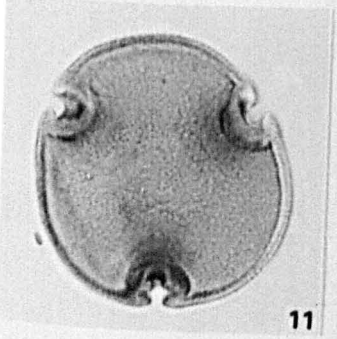
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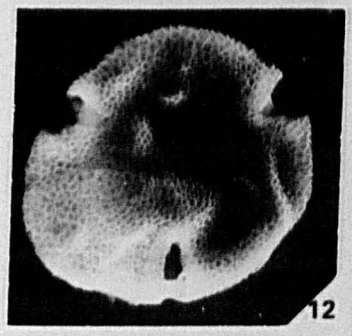
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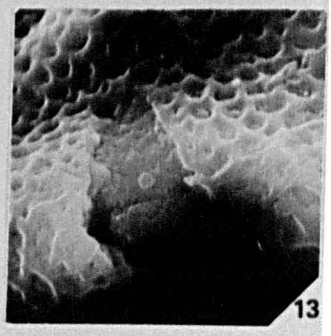
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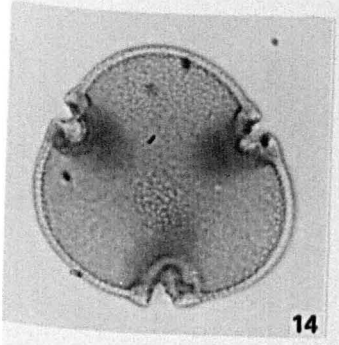
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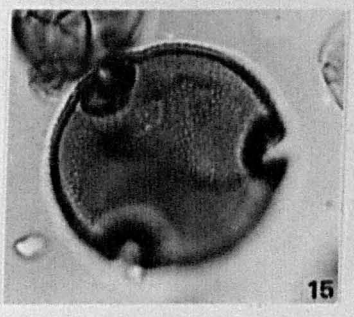
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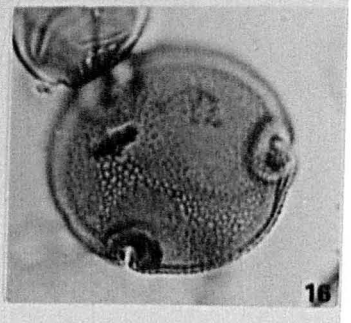
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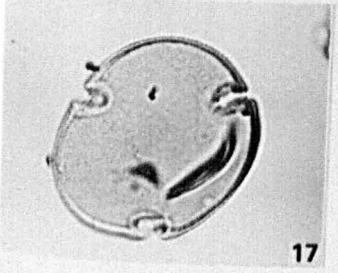
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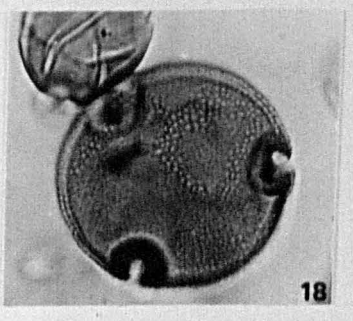
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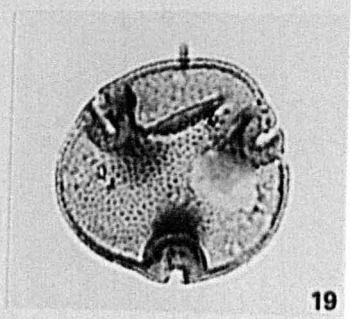
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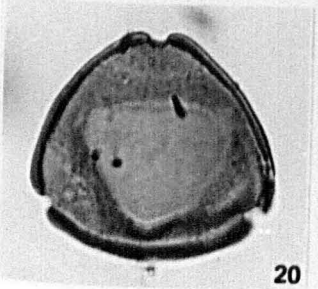
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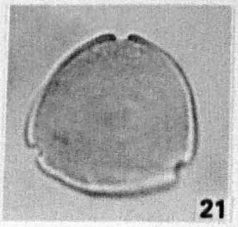
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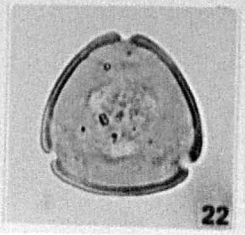
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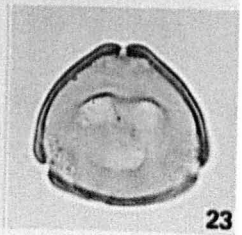
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PLATE 12

Fig.

1-7 Platycaryapollenites platycaryoides (Roche 1969) comb. nov.

1 Part of an anther, JL865b;423971 x500.

2 JL865c;3051112 x1000.

3 S.E.M. to show pattern of exine thinnings and ornament of small cones, x2000.

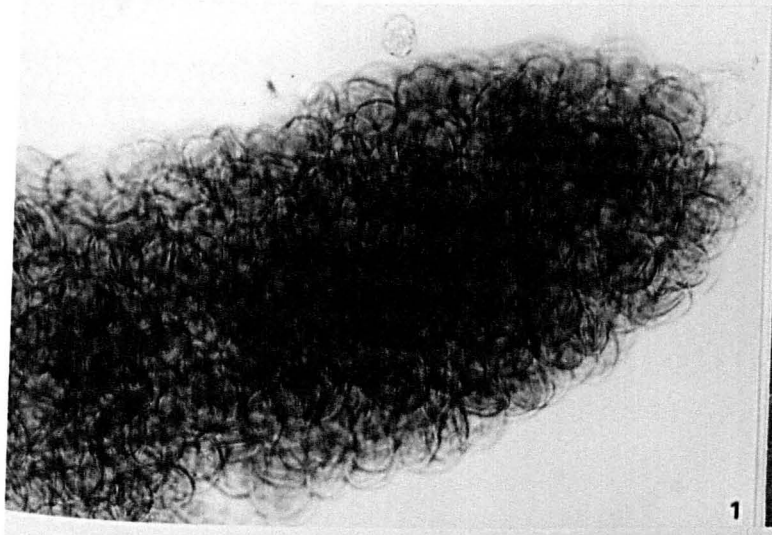
4 T.E.M. Grid B3. x10,000. Section through whole specimen showing three layered exine (see text) with areas of 'normal' and thin exine. Note the ornament of small cones and the narrow channels which cut the tectum.

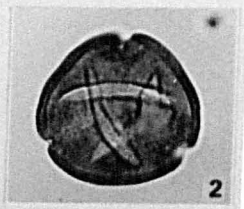
5-7 Another specimen T.E.M. Grid B3, a series of sections through the aperture.

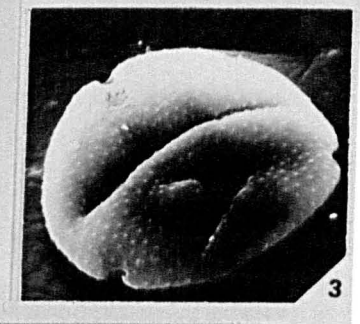
5 x10,000 oblique section gives anomalous thickness to tectum and endosexine at top left. Nexine becomes discontinuous and dies out before reaching the pore.

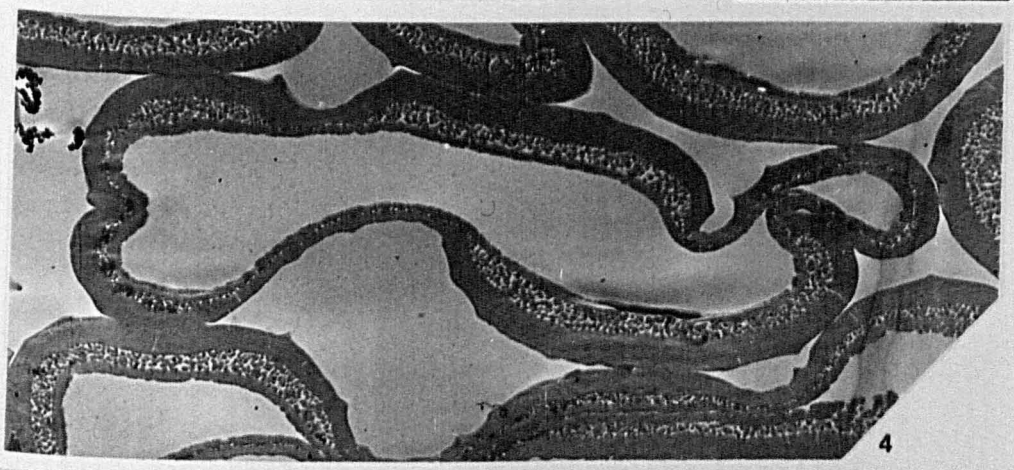
6 x c.15,750. section through the pore showing atrium without nexine and segmented nexine at the edge of the atrium.

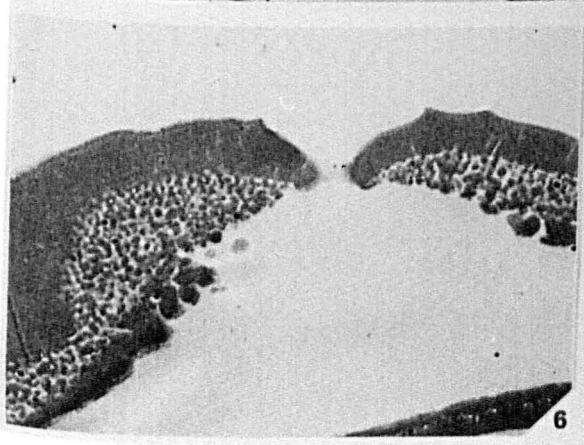
7 x10,000 section through atrium showing continuous tectum, thinned endosexine and the nexine segmented within the atrium but continuous beneath exine of normal thickness, away from the aperture.











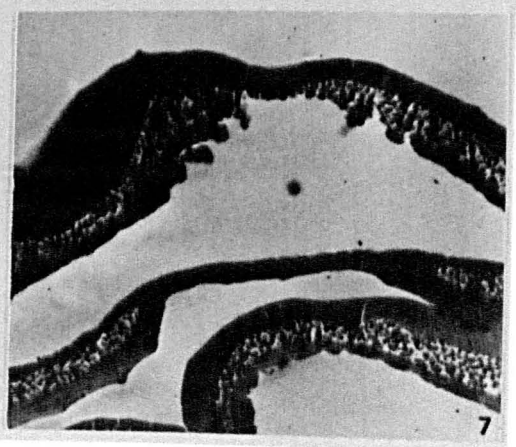


PLATE 13

All figures x1000 unless otherwise indicated.

Fig.

1 Momipites quietus (R.Pot. 1934b) Krutzsch 1972. AB68(3);4421102.

2,3 Plicatopollis swasticoides (Elsik 1974) comb. nov., JL883a;328951.

4,5,9 Platycaryapollenites anticyclus (Krutzsch & Vanhoorne 1977) comb. nov. 4 JL865f;4421000. 5 S.E.M. showing exine thinnings and ornament of cones, x1500. Stub 81, strew. 9 JL865f; 3601018.

6-8,10,11 Pistillipollenites mcgregorii Rouse 1962. 6 JL865a;2791128. 7 JL865b;291971. 8 Specimen with ornament only at the apertures, JL865a;272970. 10 S.E.M. detail of ornament, gemmae and fine grana, x3000. Stub 81, strew. 11 S.E.M. of another specimen showing elongated ornament adjacent to the aperture, x1500. Stub 81, strew.

12,13 Subtriporopollenites intrastructurus Krutzsch & Vanhoorne 1977. 12 SL96;2451005. 13 JL866a; 2411022.

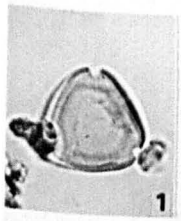
14,15 Subtriporopollenites constans Pf. 1953 subsp. constans. 14 JL898a;4421115. 15 JL865a; 3021092.

16 Subtriporopollenites anulatus (Pf.& Th. 1953) subsp. nanus, PK17D(3);EF:D47.

17 Subtriporopollenites anulatus (Pf.& Th. 1953) W.Kr. 1961. subsp. anulatus, JL867b;2881128.

continued...

PLATE 13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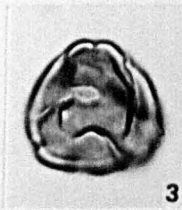
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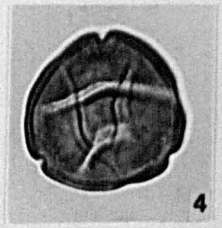
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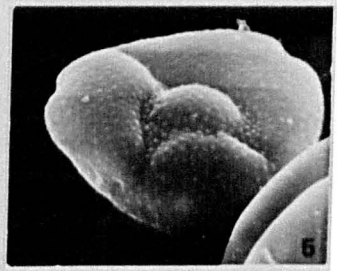
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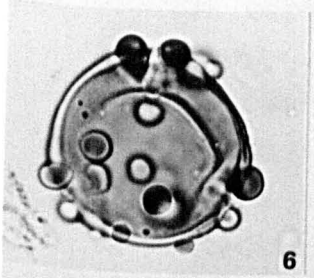
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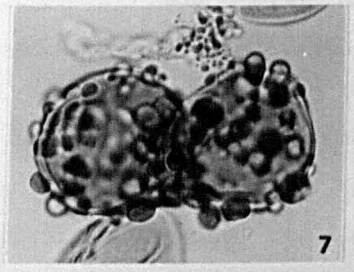
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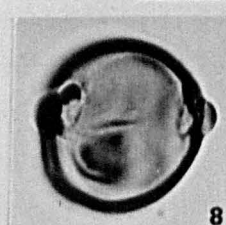
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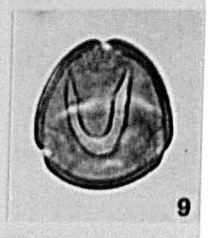
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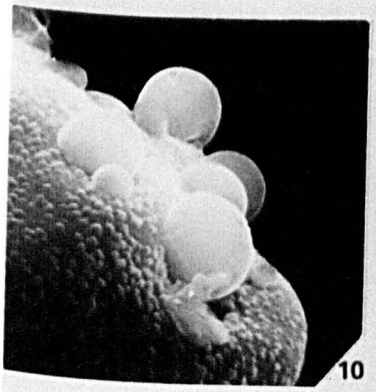
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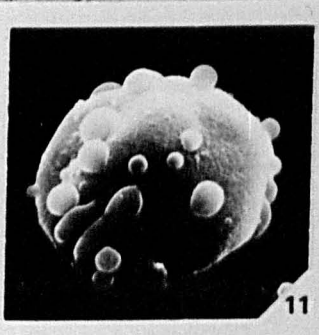
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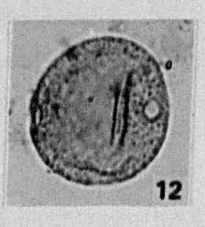
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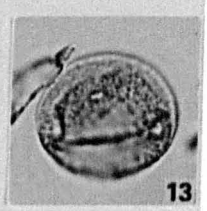
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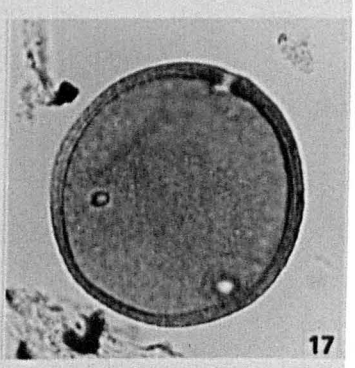
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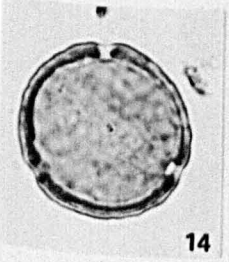
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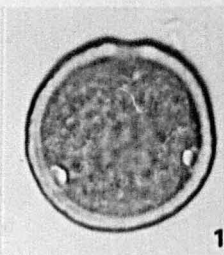
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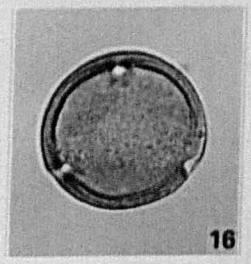
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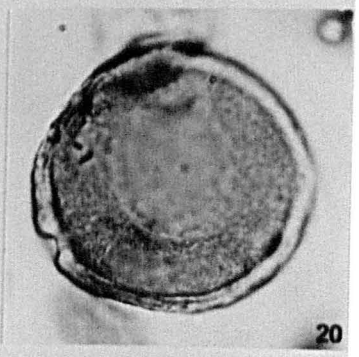
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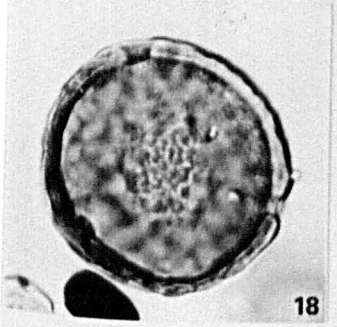
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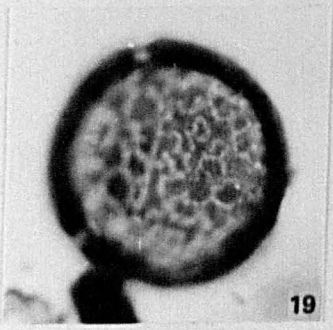
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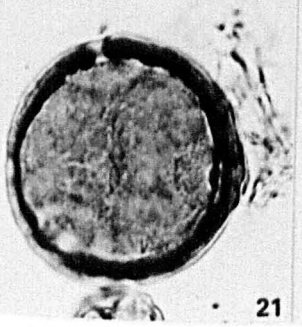
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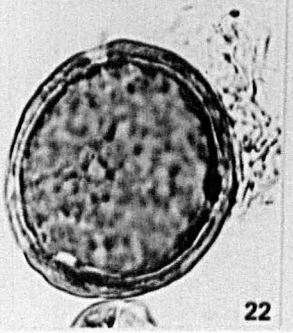
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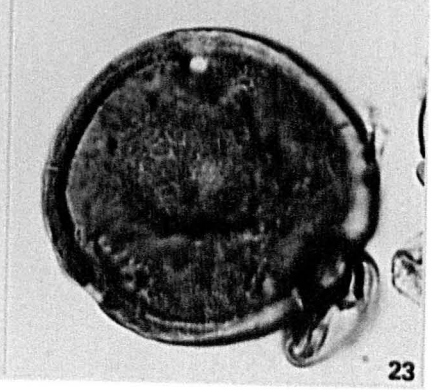
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PLATE 14

All figures x1000 unless otherwise indicated.

Fig.

1,2 Subtriporopollenites magnoporatus (Pf.& Th. 1953) W. Kr. 1961 subsp. magnoporatus, JL865a;2821000.

3 Subtriporopollenites subporatus W. Kr. 1961. JL865a;294938.

4 Triatriopollenites triangulus Frederiksen 1979. PK20D(1);EF:J32.

5-7,9 Triatriopollenites confusus Zaklinskaia 1963. 5 PK4/1;EF:K42. 6 PK21D(2);EF:040/2. 7,9 Specimens transitional to Triatriopollenites subtriangulus. 7 PK21D(2);EF:V37/1. 9 PK21D(2);EF:K38/3.

8,15 Tria triopollenites roboratus Pflug 1953b. 8 JL867a; 3211089. 15 JL866c;321910.

10-12 Triatriopllenites subtriangulus (Stanley 1965) Frederiksen 1979. 10 OGA/a;3491038. 11 KH /3; EF:041/1. 12 JL866c;270921.

13,14,16-18 Triporopollenites plektosus Anderson 1960. 13 JL866c;3101102. 14 PK21D(3);EF:Y32/1. 16 JL867a, specimen lost. 17 JL865c;3501078. 18 JL865/b;441969.

19,20 cf. Triporopollenites plektosus, folded specimens with triangular outline. 19 JL865b;448974. 20 JL865b;4181085.

21-25 Triporopollenites robustus Pflug 1953a. 21,22 Thin walled specimens showing baculate structure. 21 JL866c;258915. 22 JL866a;2751031. 23 Specimen with thick exine and an inner body, JL887/3;4151099. 24 Specimen with thick ektexine, JL887/2;3981076. 25 Large, thin-walled specimen, transitional to Triatriopollenites aroboratus, JL887/2;452962.

26-28 Triporopollenites sp. undifferentiated. 26 JL867b; 2551090. 27 AB60(3);4981011. 28 AB60(3);320910.

PLATE 14

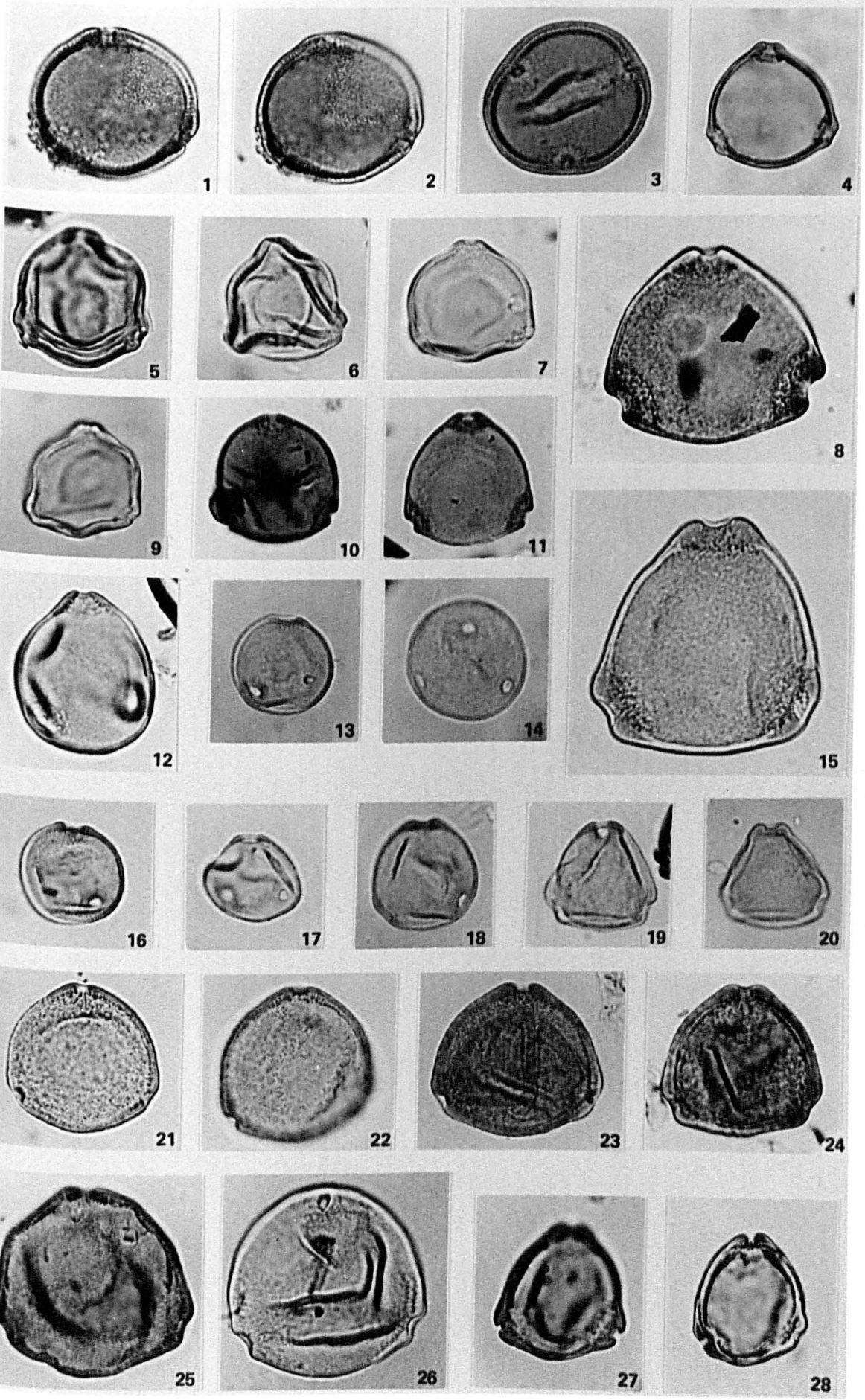


PLATE 15

All figures x1000 unless otherwise indicated.

Fig.

1,2,5-7 Gallopollis minimus Gruas-Cavagnetto 1967. 1 JL866c;3011103. 2 JL864a;4621048. 5 Cluster of Gallopollis minimus x c.900, JL887/2;428970. 6 JL864a;3301017. 7 JL864a;417978.

3,4 Caryapollenites triangulus (Pflug 1953a) Krutzsch 1961d. JL898/3;EF:T32.

8 Pentaporoites belgicus Krutzsch & Vanhoorne 1977. JL887/1;3821075.

9 Labrapollis cf. globosus CH17c(1);355999.

10 Labrapollis labraferus (R. Pot. 1931b) Krutzsch 1968. JL865f;2751021.

11,15 Brosipollis striatobrosus (Krutzsch 1961) Krutzsch 1968a. AB60(2);3721100.

12-14 Interporopollenites proporus Weyl.& Krieger 1953. SL31/2;331952.

16,17 Basopollis orthobasalis (Pflug 1953a) Pflug 1953b. JL866a;4221018.

18,19 Plicapollis pseudoexcelsus (Krutzsch 1958) Krutzsch 1961d. 18 JL898c;EF:F57/3. 19 JL867b;368918.

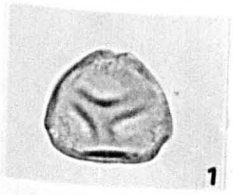
20 Nudopollis endangulatus (Pflug 1953a) Pflug 1953b. JL898a;EF:M24.

21-23 Nudopollis terminalis (Pflug 1953a) Pflug 1953b. 21 JL864b;4751092. 22 JL898a;EF:E30. 23 AB64(2); 4111022.

24,25 Pompeckjoidaepollenites subhercynicus (Krutzsch 1954a) Krutzsch 1967. JL898a;EF:L40/4.

26 Thomsonipollis magnificus (Th.& Pf. 1953) Krutzsch 1961b. AB60(2);486962.

PLATE 15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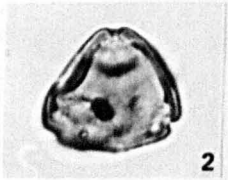
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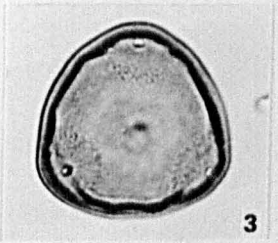
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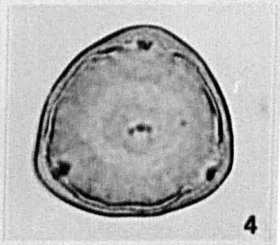
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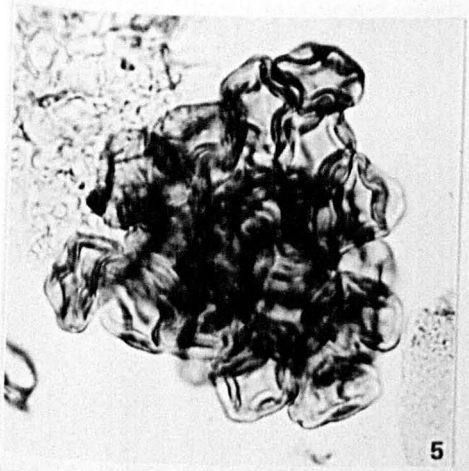
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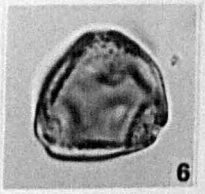
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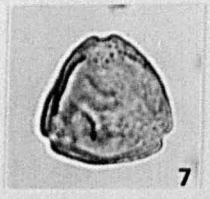
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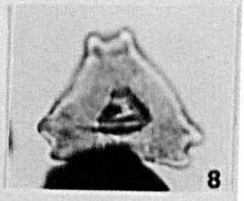
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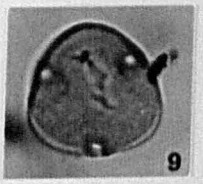
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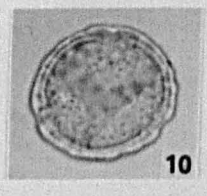
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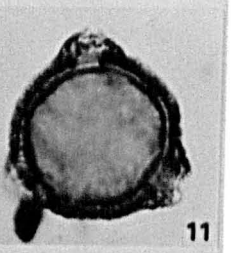
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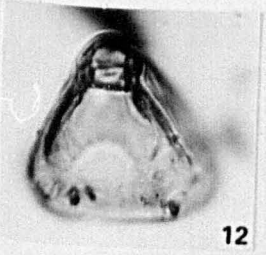
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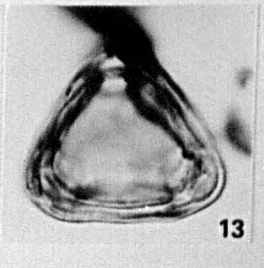
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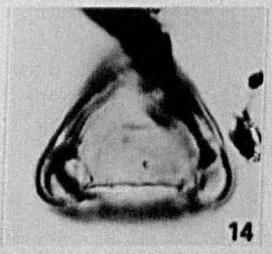
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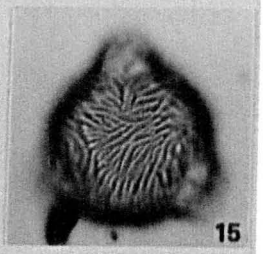
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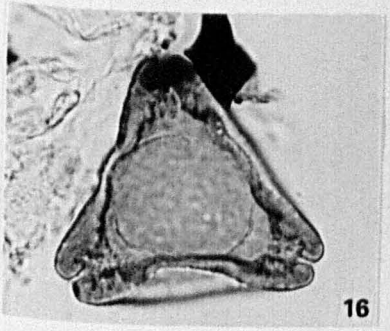
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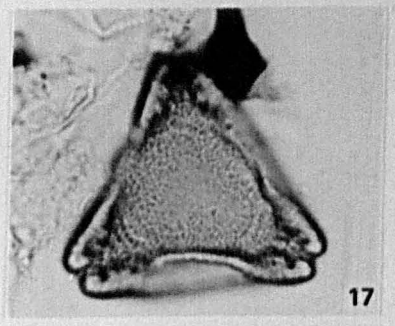
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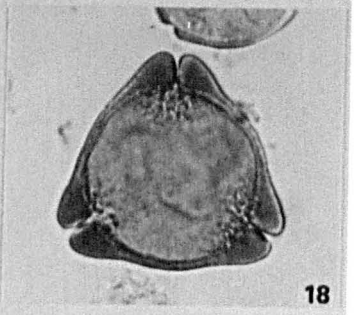
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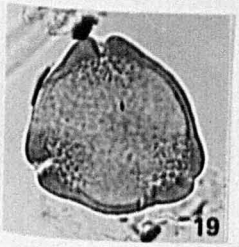
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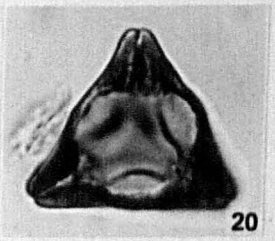
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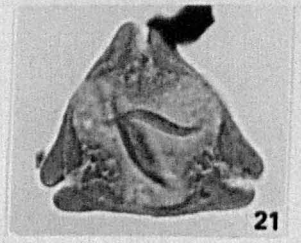
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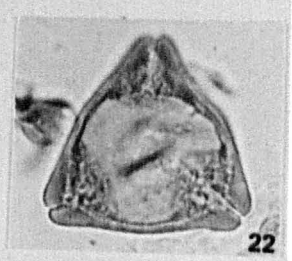
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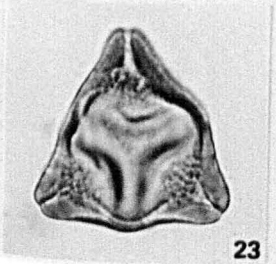
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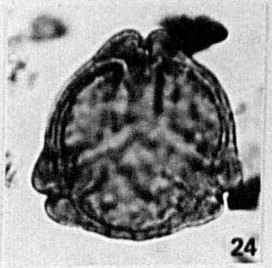
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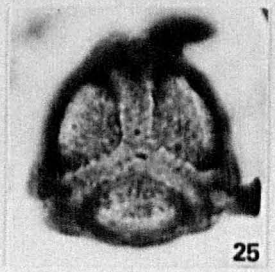
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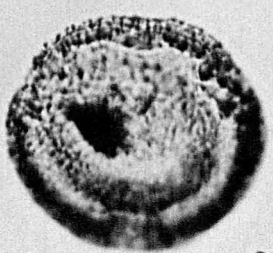
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PLATE 16

All figures x1000 unless otherwise indicated.

Fig.

1-3 Trudopollis hammenii Roche 1969. 1 Aperture structure, PB13(1);3451058. 2 Another specimen, optical section, 3 ornament, OG1c(2);2051089.

4,5 Reevsiapollis triangulus (Mamczar 1960) Krutzsch 1970b. 4 JL867/c;4011079. 5 KH/1, specimen lost.

6,7 Stephanoporopollenites hexaradiatus Pf.& Th. 1953. subsp. tribinae W.Kr. 1961d. 6 OGB/3;4521051. 7 PK20D(1);EF:M33/4.

8 Stephanoporopollenites hexaradiatus Pf.& Th. 1953. subsp. semitribinae W.Kr. 1961d. SL29/1;4081065.

9 Vacuopollis semiconcavus Pflug 1953b. JL867/b; 3701032.

10,11 Alnipollenites trina (Stanley 1965) Norton 1969. 10 OG28(4);4511032. 11 OG28(4);3721121.

12,13 Alnipollenites verus Potonié 1934b. 12 JL865f; 3321014. 13 JL865b;3501025.

14-17 Ulmipollenites tricostatus (Anderson) Fredericksen 1980. 14 x1250 CH6E(1);4351091. 15 AB63(2); 4001002. 16 JL865a;2821078. 17 JL885a;4621047.

18 Polyatriopollenites stellatus (R.Pot.& Ven.) Pflug 1953b. AB70(2);332915.

19,20 Parsonidites britannicus Gruas-Cavagnetto 1976a. 19 AB68(3);4111102. 20 AB68(3);4451102.

21,25 Persicarioipollis persicarioides Krutzsch 1966. 21 LR17/1;363952. 25 JL898c;EF:D27/2.

22 Erdtmanipollis sp. PK4/19, single spore mount.

23 Periporopollenites sp. OG11c(1);388971.

24 Interpollis velum Krutzsch 1961d. LR14/2;3671062.

26-30 Interpollis supplingensis (Pf.1953a) Krutzsch 1961d. 26,27 JL887/2;2651058. 28,29 JL887/2;4021078. 30 JL866b;2781052.

PLATE 16

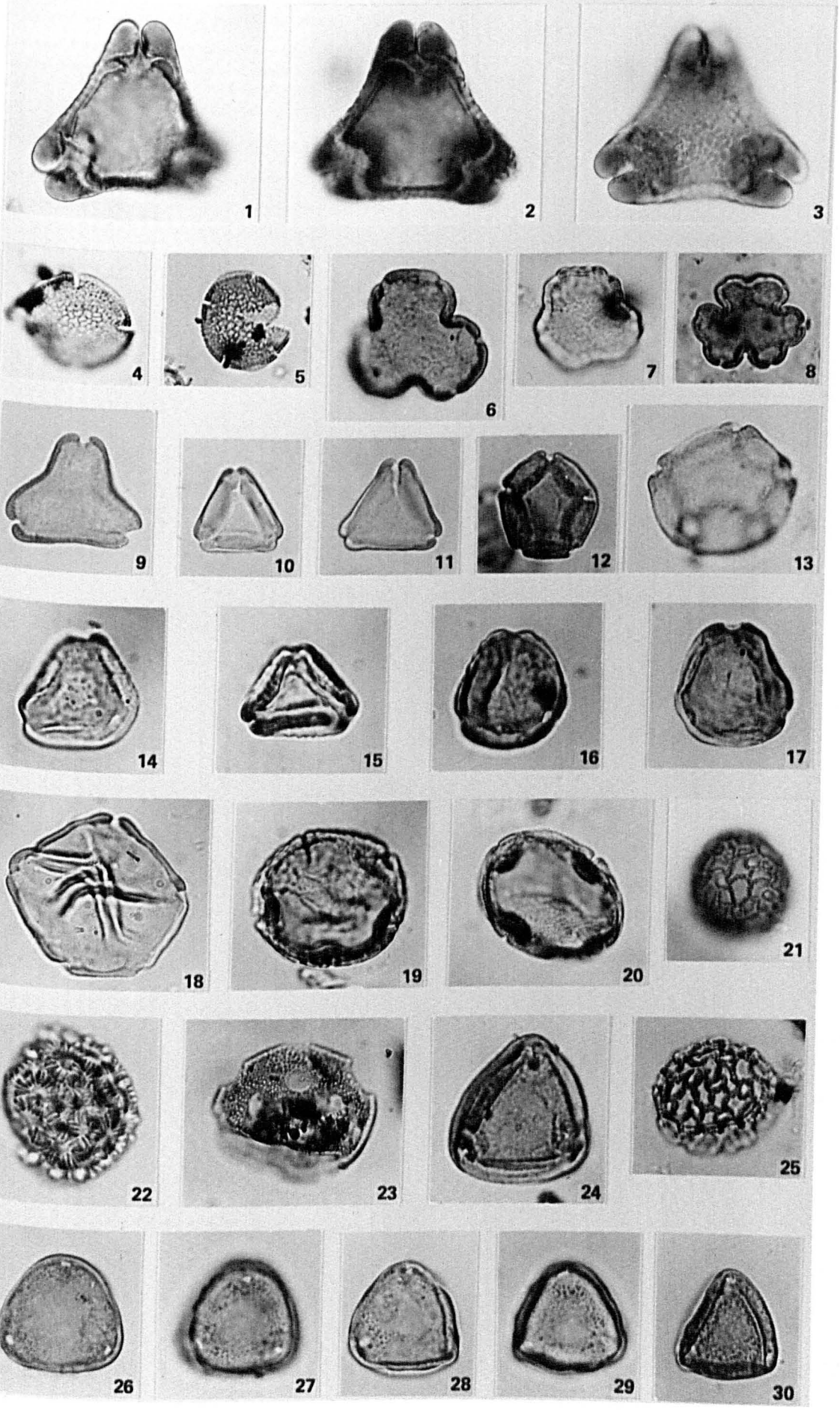
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PLATE 17

All figures x1000 unless otherwise indicated.

Fig.

1 *Anacolosidites pseudoefflatus* Krutzsch 1959b. AB60(2);483990.

2-4 *Interpollis messelensis* Krutzsch 1961d. 2 JL865b; 2551079. 3,4 JL864b;418909.

5,6,9 *Carpolithes* sp. B Collinson 1978; monocolyledonous fruit. 5 Whole specimen x50. 9 Detail of cell structure x80, JL866Fc;3481031. 6 Another specimen, cell structure x80, JL866Fc;2851017.

7 *Riccisporites tuberculatus* Lundbland 1954. PB13(1); 445975.

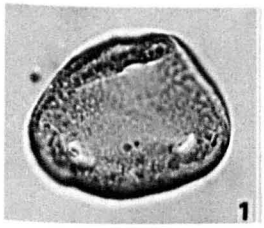
8,11,13,14 *Typha*-like seed with part of the fruit attached. 8 Whole specimen x50. 11 Detail of operculum x c.130,JL866Fa;4221055. 13,14 Another specimen, JL867Fc;3391072. 13 Detail of cell structure, x c.130. 14 Whole specimen x50.

10 *Ericipites* sp. NB1(4);439982.

12 Unidentified fruit x50, JL867Fc;3781042.

15 Family Typhaeceae; probably *Typha*, fruit x80 JL867Fd;205979.

PLATE 17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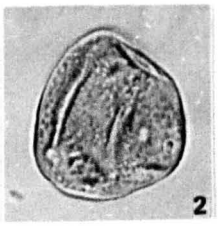
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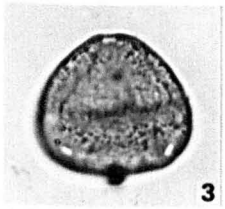
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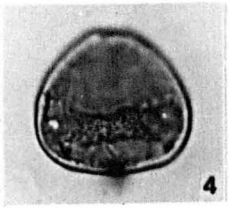
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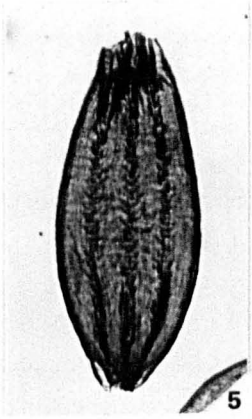
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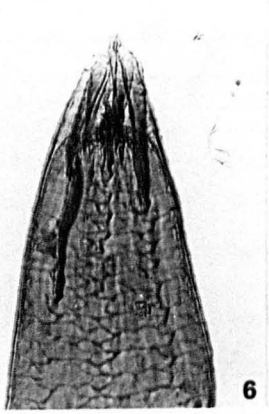
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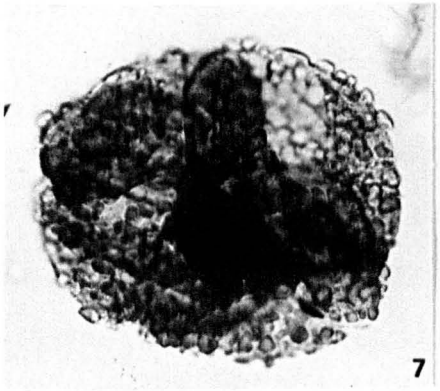
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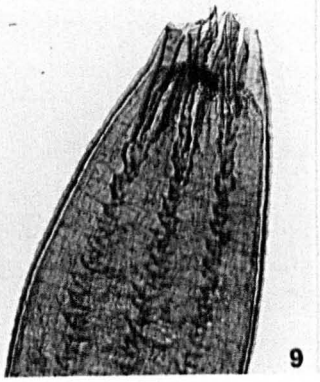
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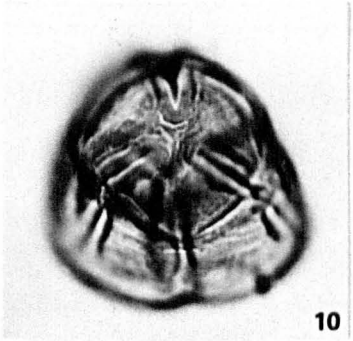
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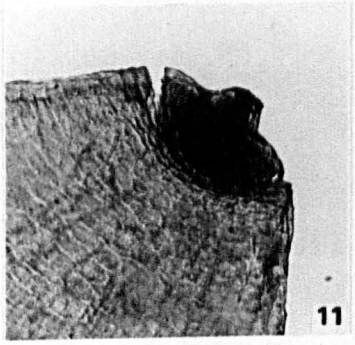
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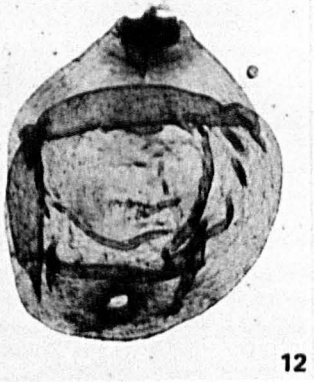
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PLATE 18

All figures x500 unless otherwise indicated.

Fig.

1 cf. Cordosphaeridium fibrospinosum JL885b;3051105.

2 ?Thalassiphora sp. JL898a;EF:Q40/1.

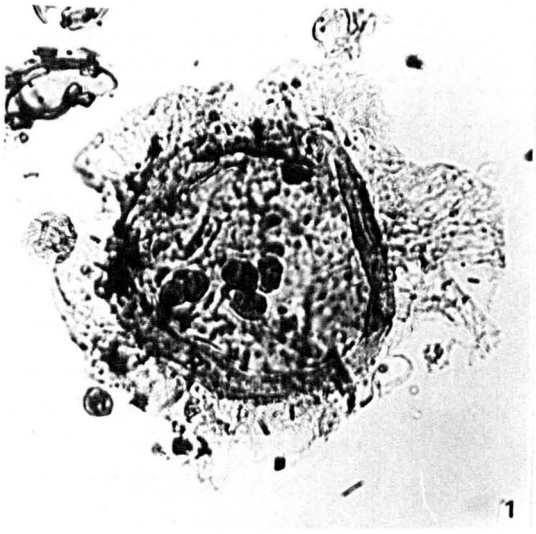
3,4 Alisocysta margarita (Harland) Harland 1979. 3 PB8b;3591095 x1000. 4 PB8b;414924 x1000.

5 ?Adnatosphaeridium patulum Williams & Downie 1966. OG9C(3);4751084.

6,7 Achomosphaera alcicornu (Eisenack) Davey & Williams 1966a. 6 PB8c/3;445982. 7 PB13(1);2981002.

8 cf. Apectodinium homomorphum (Defl.& Cooks.) Lentin & Williams 1977. AB57(2);3801045.

9-11 Apectodinium homomorphum (Defl.& Cooks.) Lentin & Williams 1977. 9 JL898a;295978. 10 JL898/2; EF:Q39/3. 11 Detail of processes, x1000 JL898/2; EF:Q39/3.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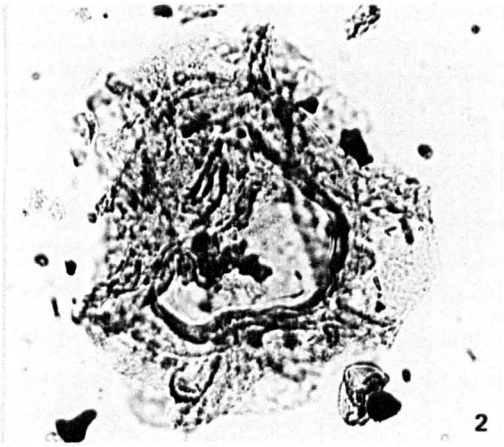
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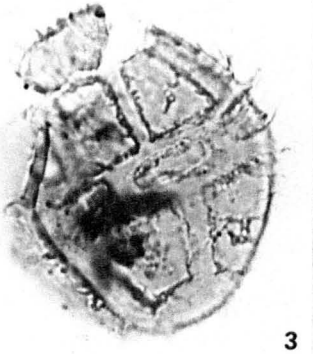
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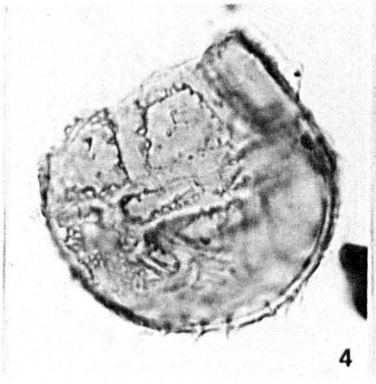
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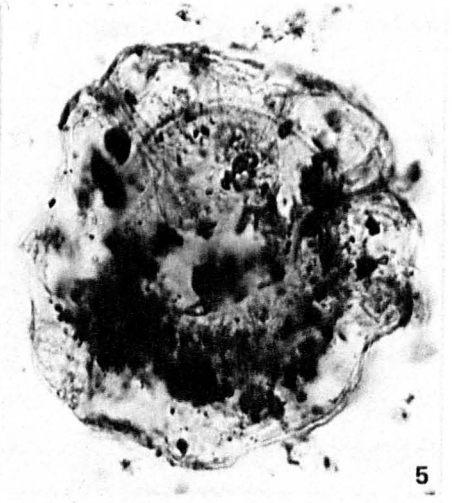
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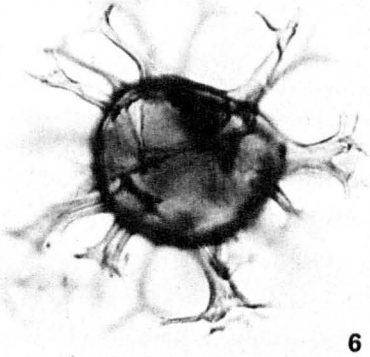
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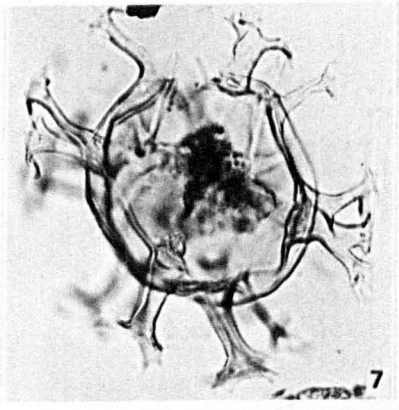
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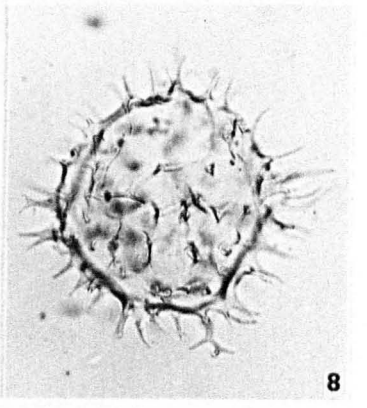
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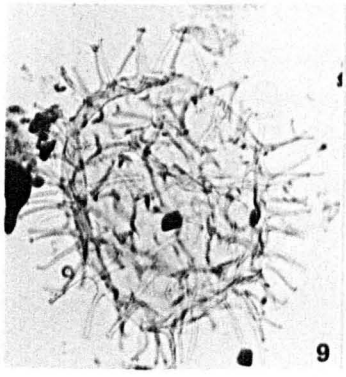
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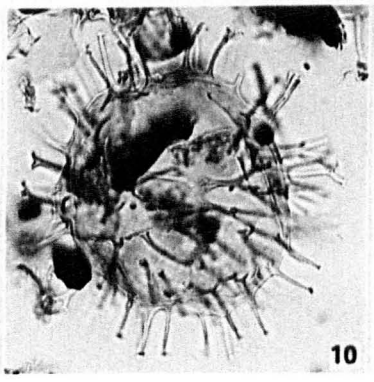
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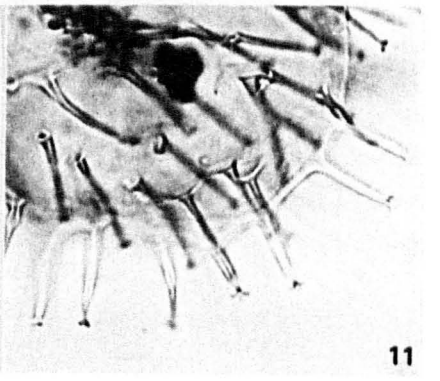
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PLATE 19

All figures x500.

Fig.

1 Apectodinium hyperacanthum (Cooks.& Eis.) Lentin & Williams 19-7. CH6E(1);340928.

2,3 Apectodinium parvum (Alberti) Lentin & Williams 1977. 2 SL10/16, single mount. 3 JL898/7;3951120.

4,9,11 Areoligera senonensis Lejeune-Carpentier 1938. 4,9 PB13(1);310945. 11 PB12/1;322925.

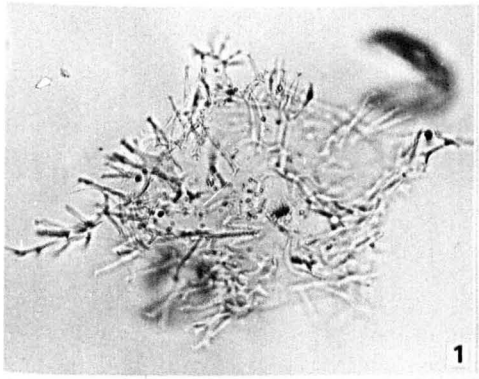
5,7 "Cleistosphaeridium" group. 5 CH16D(2);3301038. 7 CH16D(2);351991.

6 Apectodinium quinquelatum (Williams & Downie) Costa & Downie 1979. SL40/2;305948.

8 Cordosphaeridium sp. PB8b;3451095.

10 Cordosphaeridium fibrospinosum Davey & Williams 1966b. CH17c(2);2751032.

12,13 Areoligera sp. PB16(4);3321092.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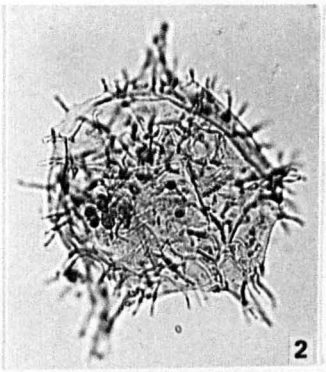
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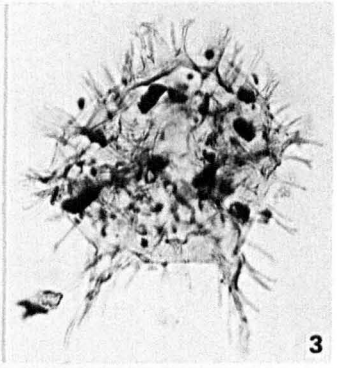
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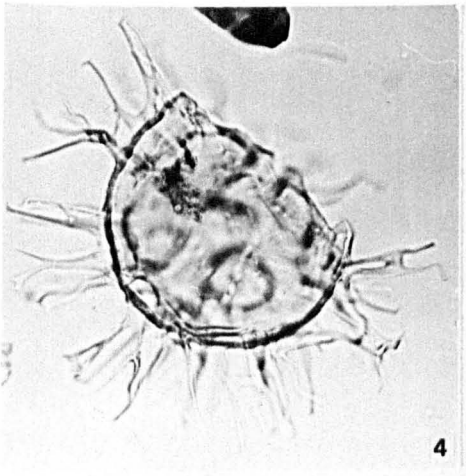
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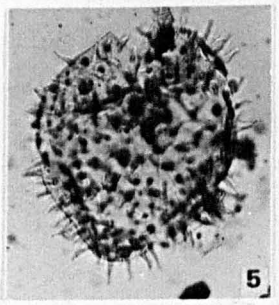
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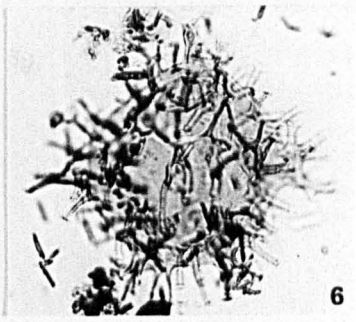
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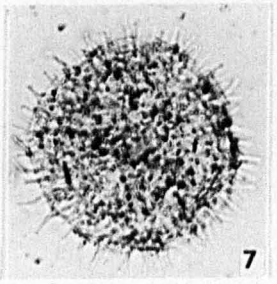
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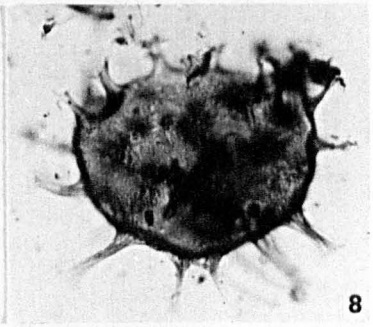
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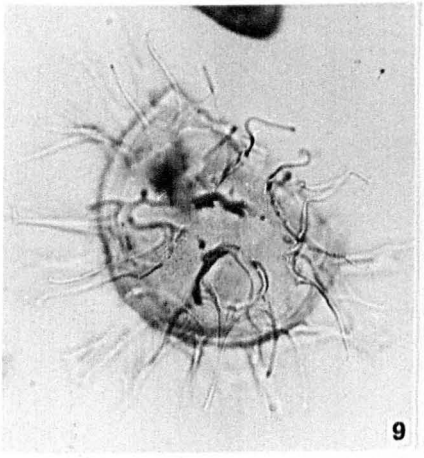
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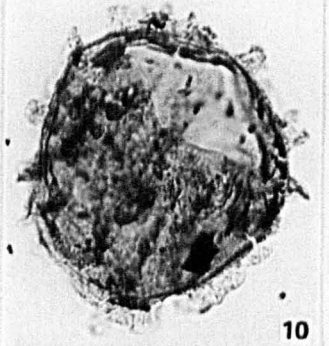
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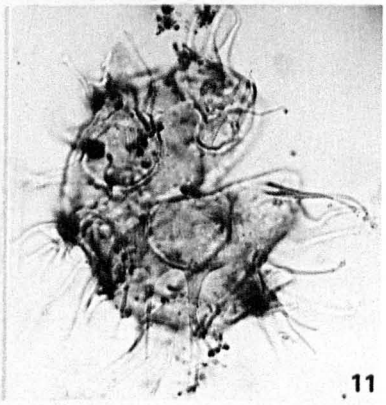
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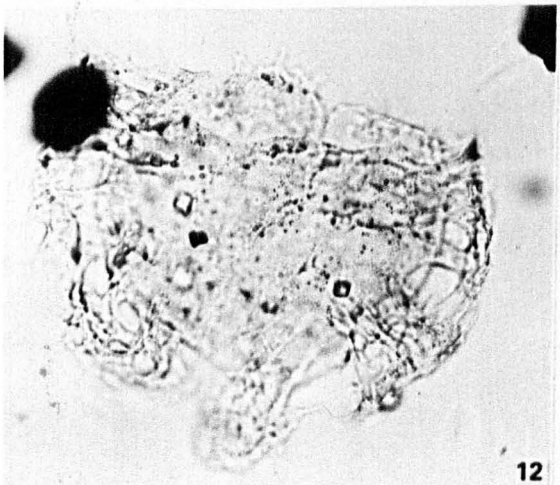
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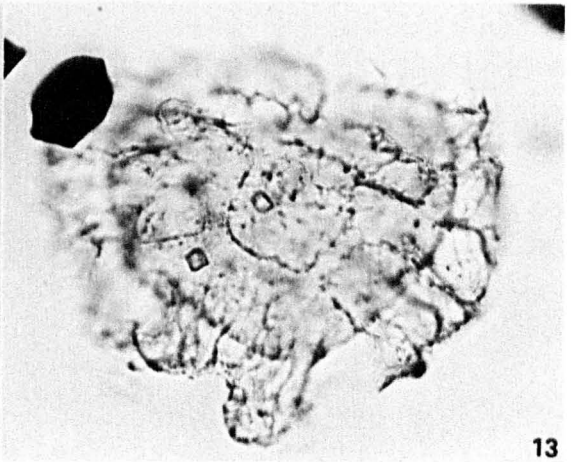
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PLATE 20

All figures x500 unless otherwise indicated.

Fig.

1 *Cordosphaeridium* sp. PB8c/3;3921062.

2,3,5-7 *Deflandrea dartmooria/oebisfeldensis*. *2,3,5,6* OGB/4;372995. *7* PB8c/2;4821053. *11* PB8c/3;4711121, x400.

4 *Cordosphaeridium inodes* (Klumpp) Eisenack 1963b. PB8b;3621092.

8-10 *Deflandrea* sp. *A*. *8* CH18D(2);4131095. *9* SL10/10, single mount. *10* CH18D(2);2821121.

12 *Deflandrea heterophlycta* Deflandre & Cookson 1955. AB52(2);5131032.

13 *Deflandrea phosphoritica* Eisenack 1938. OG27(4); 338989.

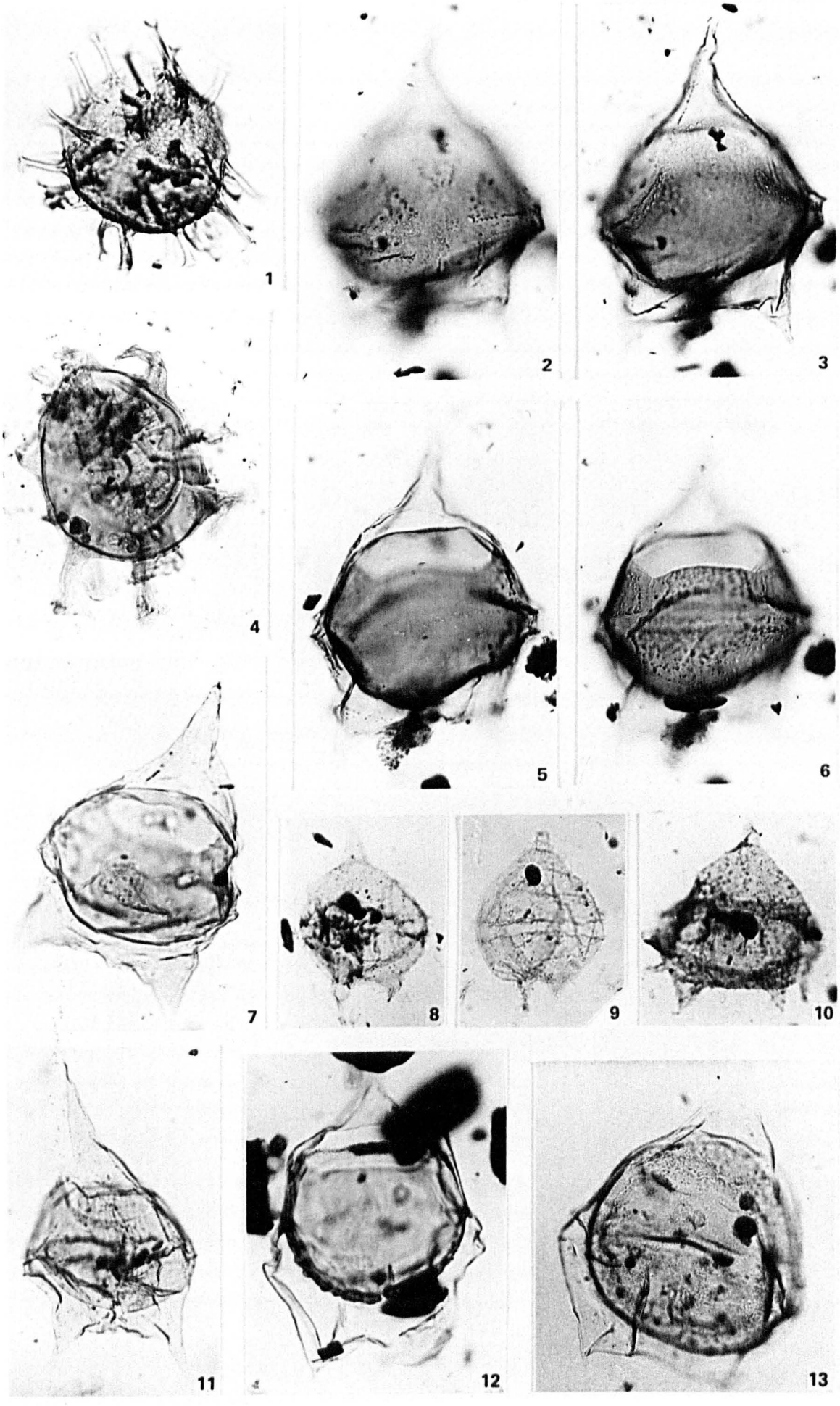
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PLATE 21

All figures x500 unless otherwise indicated.

Fig.

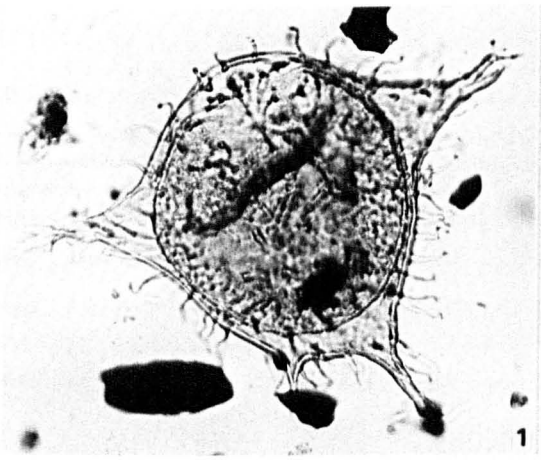
1 *Dracodinium solidum* Gocht 1955. AB52(2);461995.

2-6 *Glaphrocysta pastielsi* (Defl.& Cooks. 1955) Stover & Evitt 1978. 2 Detail of trabeculae x1000, 3 same specimen showing apical archeopyle, OGB/3;4411085. 4,6 Another specimen, AB49(3);358990, 4 detail of trabeculae x1000.

7,10 *Diphyes colligerum* (Defl.& Cooks.) Cookson 1965a. 7 SL29c(2);3311022. 10 CH17c(2);3781072.

8,9,11-13,15 *Glaphrocysta ordinata* (Williams & Downie 1966c) Stover & Evitt 1978. 8,11 PB8c/3;4701078. 9,12 PB8c/3;325981. 13,15 PB8c/3;485968.

14 *Hafniasphaera* sp. LR17/1;4591061.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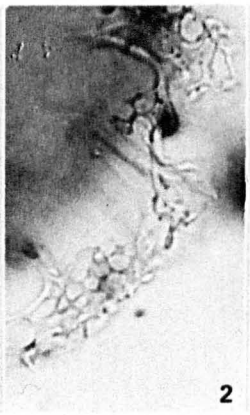
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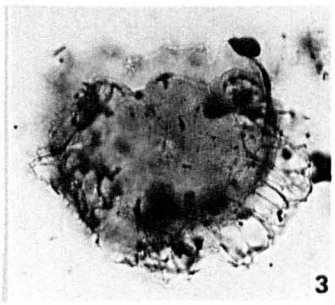
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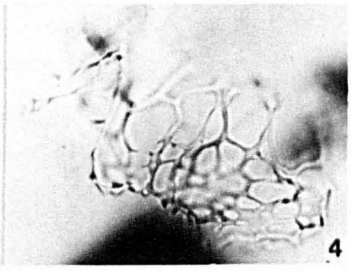
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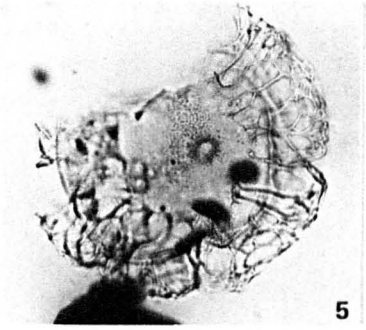
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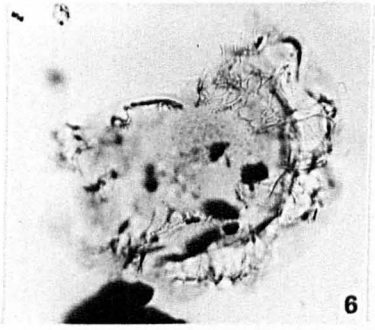
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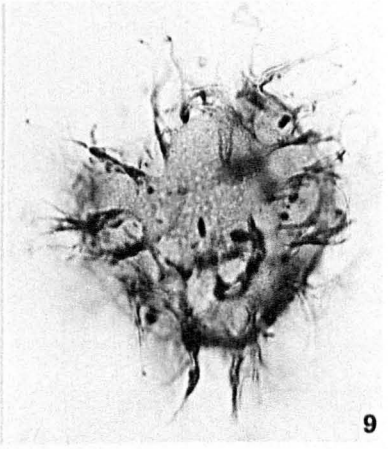
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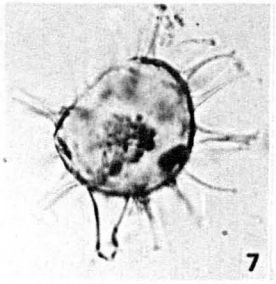
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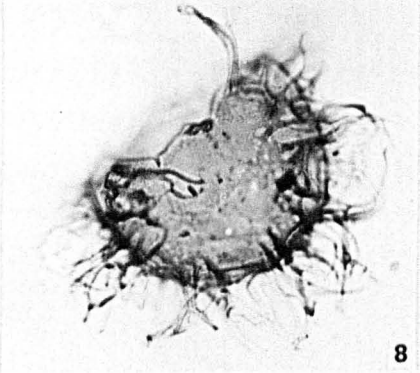
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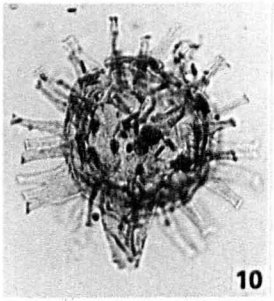
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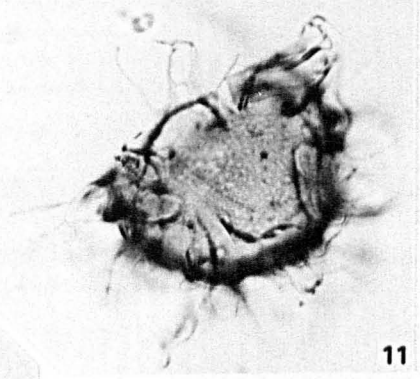
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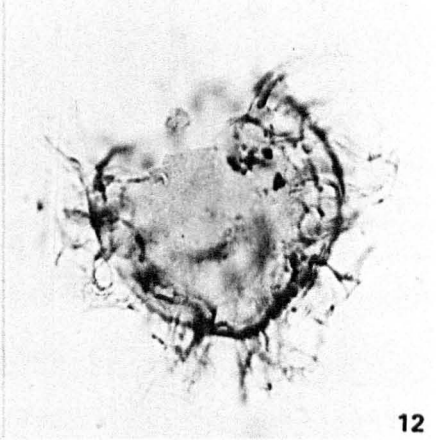
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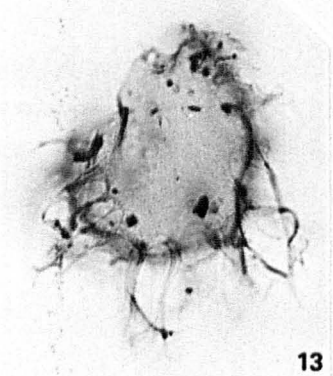
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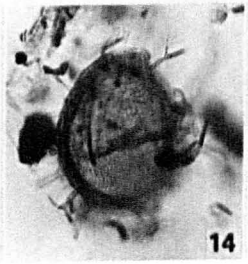
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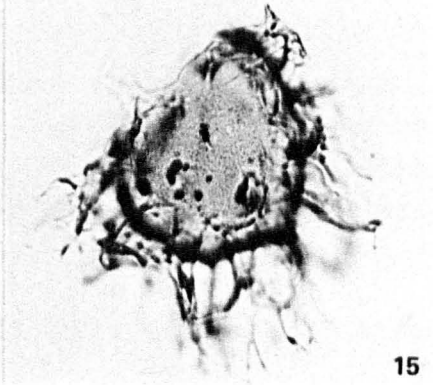
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PLATE 22

All figures x500 unless otherwise indicated.

Fig.

1,3 Glaphrocysta ordinata (Williams & Downie 1966c) Stover & Evitt 1978. 1 Specimen with operculum attached, PB8c/2;275945. 3 PB8c/2;4021062.

2,4 Hystrichokolpoma mentitum McLean 1974. PB8c/2; 4201094.

5 Glaphrocysta cf. retiintexta (Cookson 1965a) Stover Evitt 1978. PB8c/2;392985.

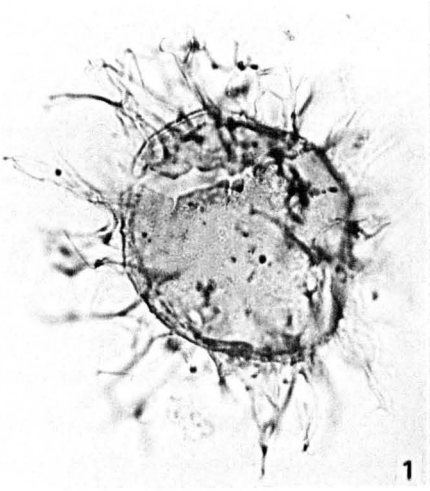
6,9,11 Hystrichosphaeridium sp. cf. H. patulum Davey & Williams 1966b. 6 SL29c(1);4481051, x750. 9,11 SL29c(1);4501021, x c.900.

7,10,12 Hystrichosphaeridium tubiferum (Ehrenburg 1838) Deflandre 1937b emend. Davey & Williams 1966b. 7 PB8c/3;441912. 10,12 PB8c/3;4481091.

8,13 Homotryblium pallidum Davey & Williams 1966b. JL898a;359955.

14 Sentusidinium sp. PK21D(2);432974 x750.

15 Homotryblium sp. JL898/7;279987.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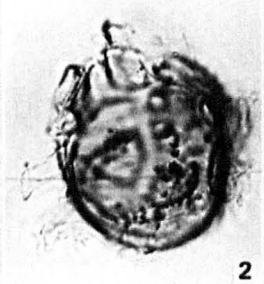
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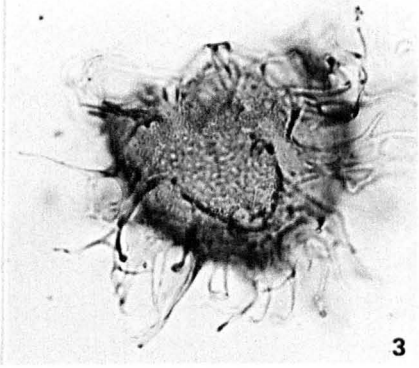
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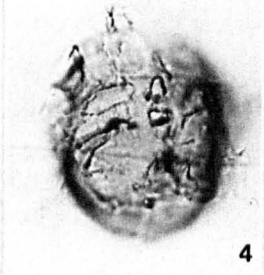
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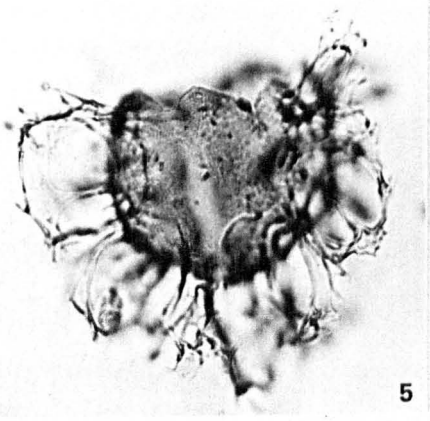
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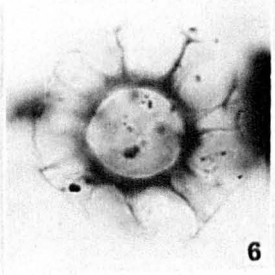
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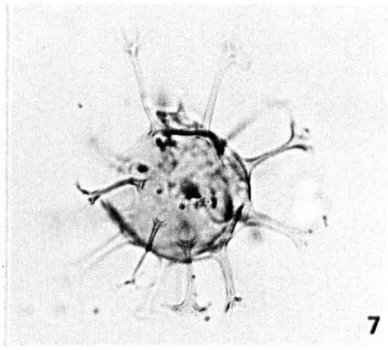
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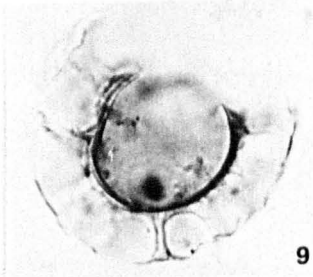
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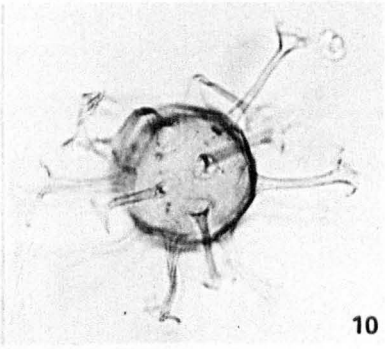
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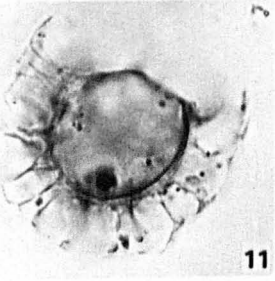
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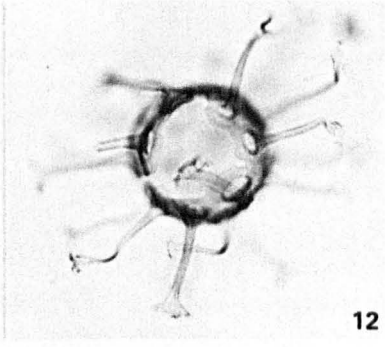
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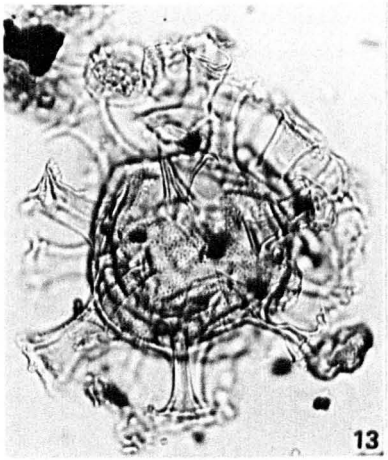
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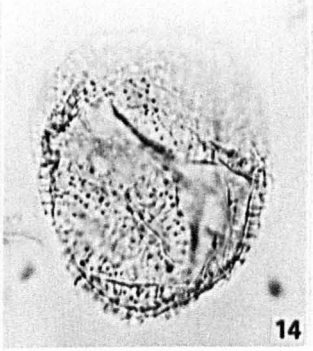
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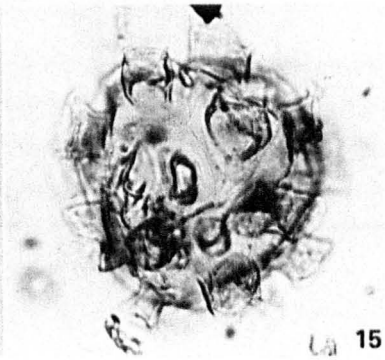
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PLATE 23

All figures x500 unless otherwise indicated.

Fig.

1 Sentusidinium sp. LR3B/1;342926 x750.

2-4 ?Microdinium sp. 2 Schumacker-Lambry & Chateauneuf 1976 x1000, PB8b;392918.

5 Gonyaulacysta jurassica (Defl.) Norris & Sarjeant 1965. AB47(2);488988.

6 Palaeostomocystis laevigata Drugg 1967. x1000, PB8b;3641062.

7 Nannoceratopsis gracilis Alberti 1961 emend. Evitt 1962. x c.750, OG27(4);3211035.

8,13,14 ?Trichodinium sp. 8 CH6E(1);302982 x750. 13 CH6E(1);4321090 x750. 14 CH12D(1);3341020 x500.

9 Stephanelytron redcliffense Sarjeant 1961a. CH18c(2);4121044.

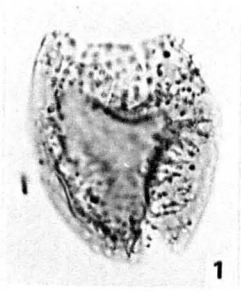
10 Microdinium sp. AB52(2);422915, x1000.

11,12 Operculodinium centrocarpum (Defl.& Cooks) Wall 1967. LR17/1;320941. 11 Whole specimen, 12 x1000, detail of process.

15 Tubidermodinium sp. CH6E(1);422965.

16-18 Phthanoperidinium crenulatum (De Coninck) De Coninck 1977. 16 OG28(3);4901012. 17,18 OG28(3);3051058.

19 Wetzeliella lunaris Gocht 1969. LR14;356952.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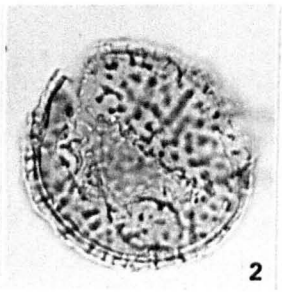
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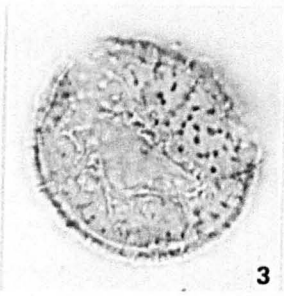
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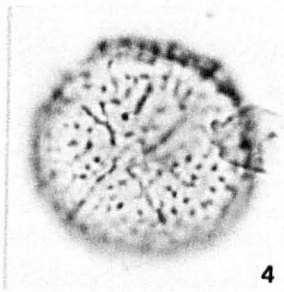
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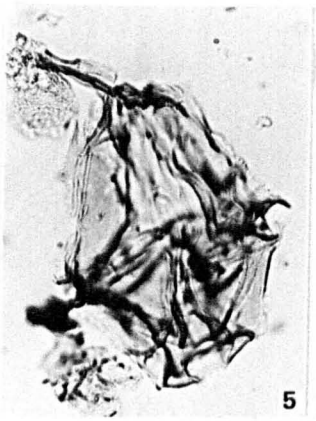
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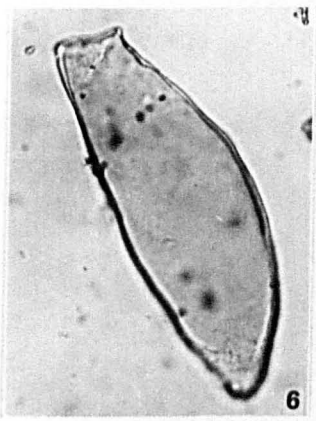
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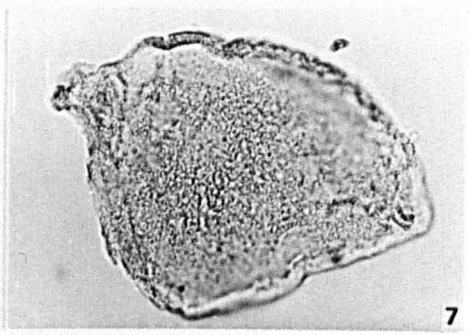
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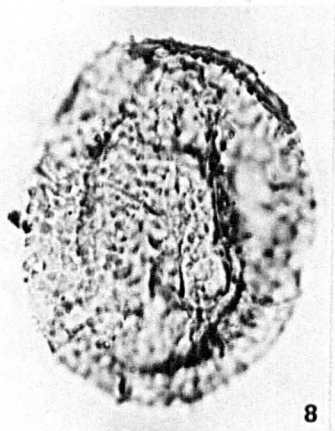
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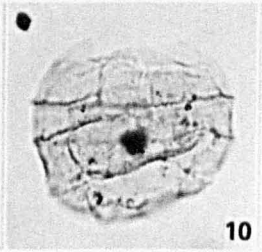
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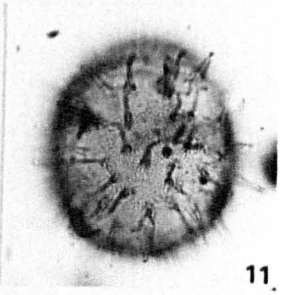
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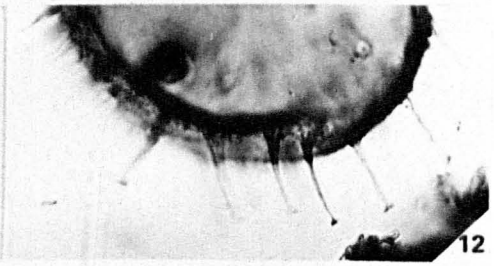
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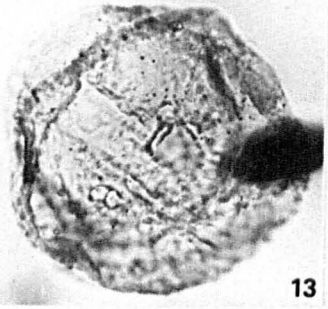
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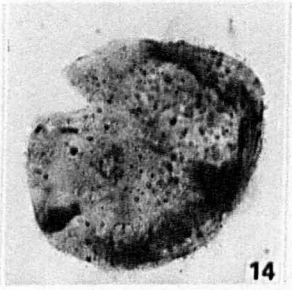
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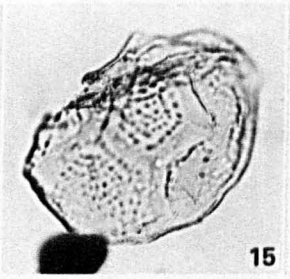
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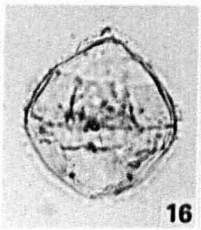
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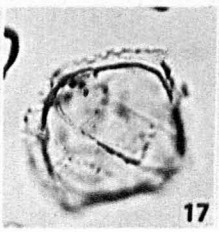
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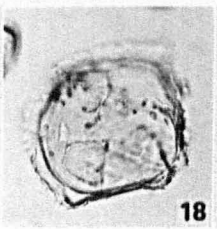
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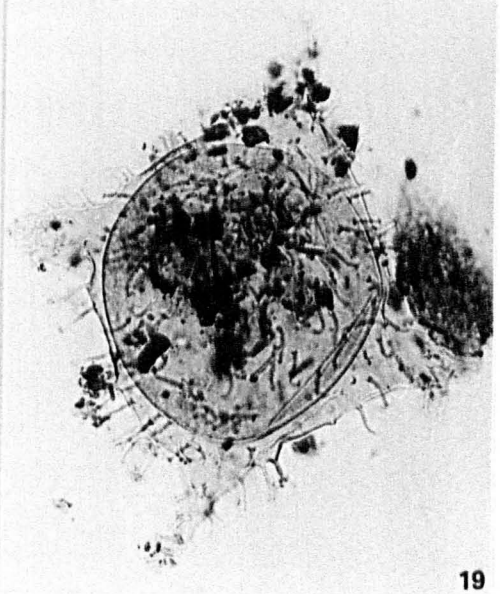
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PLATE 24

All figures x500 unless otherwise indicated.

Fig.

1 *Inversidinium exilimurum* McLean 1973b. SL29c(2); 3021072.

2,3 *Baltisphaeridium* sp. B. Gruas-Cavagnetto 1968. 2 PK4/2;3621035. 3 CH16D(2);4511081.

4 *Comasphaeridium cometes* (Valensi) De Coninck 1969. x1000, PB8b;362968.

5 *Ovoidites ligneolus* (Pot.) Thomson & Pflug 1953. JL 898/7;2951010.

6 *Paralecaniella indentata* (Defl.& Cooks.)Cookson & Eisenack 1970. OG22(2);3751005.

7 *Trigonopyxidia ginella* (Cooks.& Eis.)Downie & Sarjeant 1965. OG28(4);3601042.

8,12 *Cymatiosphaera punctifera* Deflandre & Cookson 1955. 8 x c.1600. OGB/1;specimen lost. 12 OG28(4); 4851054 x1000.

9 *Schizosporis spriggi* Cookson & Dettmann 1959. JL867c;322938.

10 Indeterminate Type 1. JL865b;445962.

11 *Horologinella apiculata* Cookson & Eisenack 1962a. x1000, PB8b;3221060.

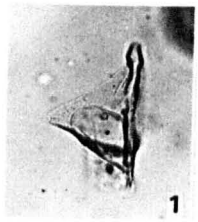
13 *Tetraporina pellucida* Naumova ex Bolkhovitina 1953. x c.750, JL864b;4401095.

14 ?Fungal spore x1000, NB1(1);3001000.

15 *Pediastrum* sp. x750, JL942c;4021045.

16,17 Pyritised diatoms. 16 SL50, water mount, specimen lost. 17 SL51, water mount, specimen lost.

18,19 *Schizosporis parvus* Cookson & Dettman 1959. 18 x750, JL864b;275930. 19 Cluster of several specimens x500, JL866c;2551078.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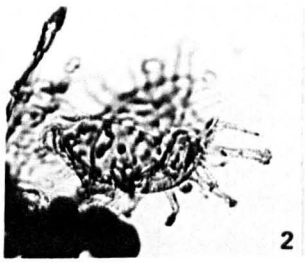
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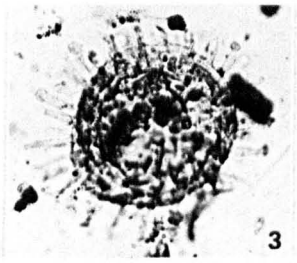
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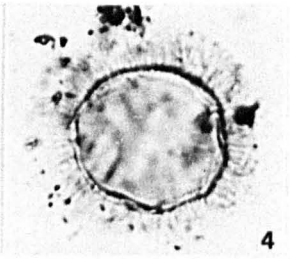
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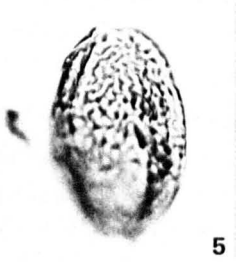
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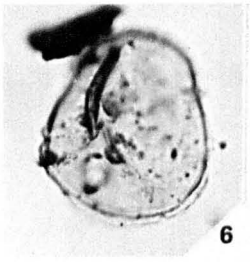
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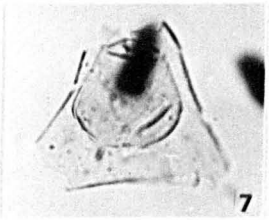
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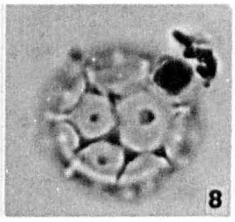
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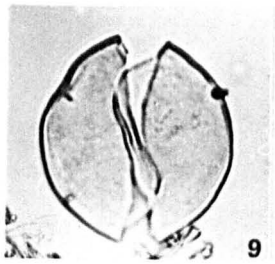
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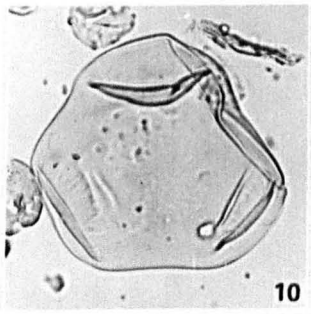
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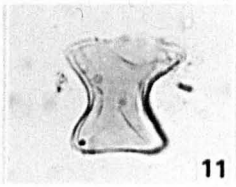
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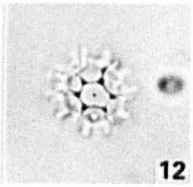
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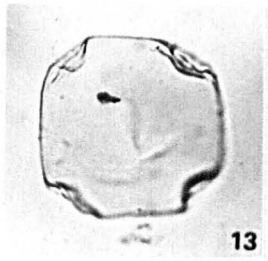
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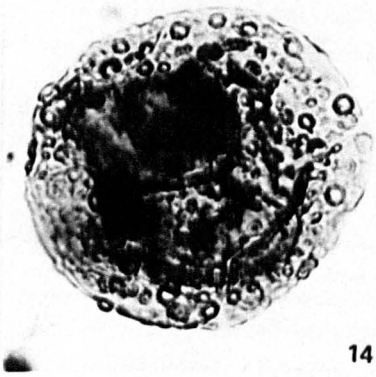
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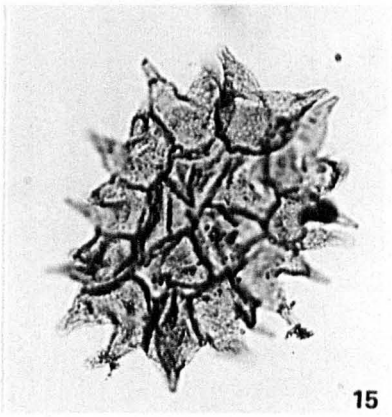
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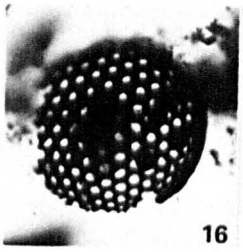
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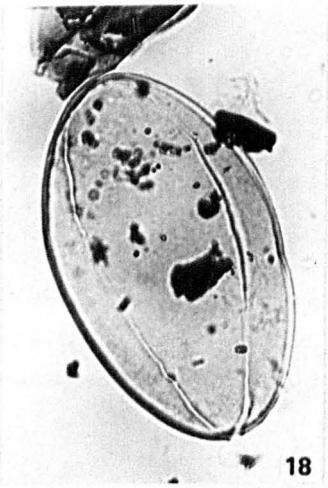
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APPENDIX 1:

LITHOLOGICAL DETAILS OF SAMPLES COLLECTED.

KEY

* Sample counted or examined in detail.

+ Sample with sparse microflora, or barren.

1. PEGWELL BAY

CAR PARK SECTION (TR.34856410)

THANET BEDS.

Reculver Silts.

PB 19 (1.04m above base of Reculver Silts) Silty sand, dusky yellow 5Y6/4, with common shells.
PB 18 * (0.5m) Silt, yellowish grey 5Y7/2.
PB 17 (0.05m) Shell seam with matrix of silty sand, yellowish grey 5Y7/2.

Upper Pegwell Marls.

PB 16 * (1.45m below base of Reculver Silts) Silty clay, yellowish grey, 5Y8/1.
PB 15 (2m) Silty clay, yellowish grey, 5Y7/1.

CLIFFS END SECTION (TR.35456439)

THANET BEDS

Lower Pegwell Marls.

PB 14 (6.20-6.25m above the Chalk) Clayey silt, yellowish orange, 10YR6/4, bioturbated.
PB 13 * (5.45-5.50m) Crepidula Band. Silt, light olive grey, 5Y7/1, with small burrows (c.4mm) filled with fine sand, light grey, N7.

Stourmouth Clays.

PB 12 * (4.43-4.48m above the Chalk) Glauconitic clayey silt, yellowish grey, 5Y7/2, bioturbated, iron-stained.
PB 11 * (3.43-3.48m) Glauconitic silty with clay lenses, yellowish grey, 5Y7/2.
PB 10 * (3.00m) Glauconitic sandy silt with clay lenses, yellowish grey, 5Y8/1.
PB 9 (2.83m) Silt, yellowish grey, 5Y7/2, iron-stained.
PB 8 * (2.23-2.28m) Silt, yellowish grey, 5Y8/1, with rare, small, carbonised plant fragments.
PB 7 (1.5-1.6m) Clayey silt, yellowish grey, 5Y7/2, bioturbated.
PB 6 (1.3-1.4m) Clayey silt, with streaks of fine silty sand, yellowish grey, 5Y7/2, bioturb ated, some iron-staining.
PB 5 * (1.05-1.15m) Glauconitic sandy silt, yellowish grey, 5Y8/1, bioturbated.

THANET BEDS continued

Cliffs End Greensand Bed.

PB 4 (0.74-0.79m above the Chalk) Glauconitic silty sand, greyish orange, 10YR/2.

PB 3 * (0.33-0.39m) Glauconitic, fine silty sand, greyish orange, 10YR7/4, bioturbated.

PB 2 (0.18-0.26m) Glauconitic sand, light greenish grey, 5GY8/1, bioturbated.

Bullhead Bed.

PB 1 * (5cm above the Chalk) Glauconitic, fine silty sand, moderate yellowish brown, 10YR6/4; matrix from Pebble Bed.

2. OLDHAVEN GAP. (TR 20706870) Composite Section.

SECTION 3. (TR 20586868 east-north-east to TR 20686872).

LONDON CLAY.

OG 26 * (0.7m above base of London Clay) Glauconitic silty clay, dark yellowish brown, 10YR4/1.
OG 25 * (0.15m) Silty clay with lenses of fine sand, light olive grey, 5Y5/1, small-scale cross-bedding.

OLDHAVEN BEDS.

OG 24 + (0.5m below base of London Clay) Very fine glauconitic sand, pale yellowish brown, 10YR6/2.
OG 23 + (1.55m) Glauconitic fine sand, pale yellowish brown, 10YR6/4.
OG 22 + (2.65m) Very fine glauconitic sand, pale yellowish brown, 10YR6/4.
OG 21 + (3.7m) Glauconitic, silty sand, pale yellowish brown, 10YR6/2, with abundant bivalves.
OG 20 + (4.75m) Glauconitic, very fine sand, pale yellowish brown 10YR6/2.
OG 19 + (5.65m) Glauconitic, very fine silty sand, pale yellowish brown, 10YR6/4, with common bivalves.
OG 18 + (5.9m) Poorly sorted, glauconitic, fine sand, moderate yellowish brown, 10YR5/4, with bivalves and occasional rounded black flint pebbles and clay lenses.
OG 17 (6.2m) Lense of silty clay at the top of the pebble bed, dark yellowish brown, 10YR4/2.
OG 16 (6.5m) Lense of silty clay within the pebble bed, dark yellowish brown, 10YR4/2.
OG 27 * (Foreshore sample from channel in base of Oldhaven Beds). Laminated silty clay, moderate brownish grey, 5YR5/1.

WOOLWICH AND READING BEDS.
Woolwich Marine Beds.

OG 15 + (7.0m below base of London Clay) Glauconitic, fine silty sand, pale yellowish brown, 10YR6/4.
OG 14 * (8.0m) Very fine, glauconitic sand, pale yellowish brown, 10YR6/4, bioturbated.
OG 13 + (9.05m) Very fine, glauconitic, silty sand, pale yellowish brown, 10YR6/4, bioturbated.
OG 12 * (9.7m) Silty sand, pale yellowish brown, 10YR6/4.
OG 11 * (10.7m) Glauconitic silty sand, dusky yellow, 5Y6/2.
OG 10 + (11.2m) Silty sand, yellowish grey, 5Y8/1, bioturbated.

Beltinge Fish Bed.

OG 9 * (11.7m) Glauconitic, silty clay, light olive grey, 5Y6/1, bioturbated with some gypsum, pyrite, charcoal fragments and small, rounded flint pebbles.

THANET BEDS.

OG 8 + (12.03m) Poorly sorted silty sand, very glauconitic, light olive grey, 5Y6/1, bioturbated.

Corbula regulbiensis Bed.

OG 7 * (Foreshore sample) Very glauconitic silty sand, light greenish grey, 5GY7/1, with Corbula regulbiensis.

SECTION 2. (East of Oldhaven Gap, TR 20736874)

THANET BEDS, continued.
Astarte tenera Bed.

OG 6 + (2.85m below base of Woolwich and Reading Beds). Silty sand, light olive grey, 5Y6/1, glauconitic, iron-stained, bioturbated.

OG 5 * (3.17m) Silty clay, pale yellowish brown, 10YR6/4, glauconitic, with charcoal fragments and abundant bivalves including Astarte.

OG 4 + (3.4m) Silty sand with clay lenses, moderate yellowish brown, 10YR5/4, glauconitic, bioturbated with much charcoal and common Astarte.

OG 3 * (3.6m) Poorly sorted glauconitic sand, light olive grey, 5Y6/1, with Corbula.

SECTION 1. (Headland c.750m. east of Oldhaven Gap, TR 21406902).

THANET BEDS.
Arctica morrisi Bed.

OG 2 * (0.9m above Concretion Band) Silty sand, light olive grey 5Y5/2, with glauconite and abundant bivalves Arctica morrisi, bioturbated.

Eutylus cuneatus Bed.

OG 1 * (0.2m below Concretion Band). Glauconitic silty sand, dusky yellowish grey, 5Y6/2.

OG 28 * (Foreshore sample, below Concretion Band). Silty clay, light grey, N7, with pyrite and bivalves, Eutylus cuneatus and Arctica morrisi.

SPOT SAMPLES. (Bishopstone Gap, TR 20706870).

OG B * Woolwich Marine Beds (c.0.1m above base). Silty sand, light olive grey, 5Y6/1, glauconitic.

OG A * Thanet Beds, Corbula regulbiensis Bed. Glauconitic silty sand, greenish grey, 5GY6/1.

3. CHARLTON SAND PIT, MARYON PARK. (TQ 419786)

WOOLWICH AND READING BEDS.

Striped Loams

Marine Sand Unit.

CH 20 (10.59m above base of the Woolwich Bottom Bed) Finely laminated sand, yellowish grey, 5Y8/1; and silty clay, greenish grey, 5GY6/1; bioturbated.

CH 21 * (10.16m) Bioturbated clay, greenish grey, 5GY8/1; with lenses of fine sand, yellowish grey 5Y8/1; some iron-staining.

Laminated beds.

CH 17 * (9.02m) Fine sand, yellowish grey, 5Y8/1; with thin lenses of clay, light olive grey, 5Y6/1; considerable iron-staining.

CH 16 * (8.78m) Light olive grey clay, 5Y6/1; with silt lenses, moderate yellowish brown, 10YR6/4.

CH 19 * (8.53m) Light olive grey clay, 5Y6/1; with abundant shells, Corbicula cuneiformis.

CH 15 * (8.48m) Iron-stained silty clay, medium light grey N6; and fine sand, yellowish grey, 5Y8/1; with common wood fragments and gypsum.

CH 14 (8.18m) Laminated silt, yellowish grey, 5Y7/2, and medium grey, N5; with lenses of fine sand, pale yellowish brown, 10YR6/4.

CH 18 * (8.15m) Laminated clayey silt, light olive grey, 5Y6/1; with lenses of silty, fine sand, dark yellowish orange, 10YR6/6; occasional leaf impressions on bedding planes.

CH 13 (7.87m) Finely laminated clayey silt, medium light grey N6; gypsum.

CH 12 * (7.67m) Finely laminated silty clay, moderate yellowish brown, 10YR5/4, pale yellowish brown, 10YR6/2, and medium grey, N5; with silty partings, dusky yellow, 5Y7/4; much gypsum.

Woolwich Shell Beds.

CH 10 (7.14m-7.19m) Stiff clay, light olive grey, 5Y6/1; with lenses of abundant fragmentary shells of Corbicula, and Brotia melanioides.

CH 11 * (6.99m) Laminated clay, medium olive grey, 5Y5/1; with some Corbicula fragments and Brotia melanioides; much gypsum on bedding planes.

CH 8 * (6.40m) Very ferruginous laminated clay, light olive grey, 5Y5/2; with fragmentary molluscs Corbicula cordata and C. cuneiformis and lenses of fine sand, moderate yellowish brown, 10YR5/4, with Hydrobia; much gypsum on bedding planes.

CH 9 * (6.27m) Clay, medium olive grey, 5Y5/1; with sandy lenses, moderate yellowish brown, 10YR5/4; abundant fragments of Corbicula cordata, C. cuneiformis, Brotia and Tympanotonus; much gypsum.

Woolwich Shell Beds. continued.

CH 7 (5.77m) Iron-stained silty clay, medium greenish grey, 5GY5/1; with shell fragments as above, gypsum common.

CH 6 * (5.61m) Shelly clay, medium olive grey, 5Y5/1, with small lenses of sand, light olive grey, 5Y6/1; common Corbicula cordata and C. cuneiformis with Ostrea sp.

CH 5 * (4.93m-4.99m) Shelly clay, olive grey, 5Y4/1, with shells as above.

Woolwich Bottom beds.

CH 4 * (4.39m) Mottled clay, moderate yellowish brown, 10YR5/6, dusky yellow 5Y6/4 and yellowish grey, 5Y8/1, bioturbated.

CH 3 + (3.66m) Fine glauconitic sand, greyish yellow, 5Y8/4 and dusky yellow, 5Y6/4.

CH 2 * (0.76m) Fine glauconitic sand, dusky yellow, 5Y6/4; with lenses of laminated silty clay, greenish grey 5GY6/1.

CH 1 * (0.13m) Poorly sorted glauconitic sand, pale olive, 10Y6/2 (matrix of pebble bed).

4. SHORNE WOOD (near Cobham, Kent, TQ 67306980)

This material was obtained from the Institute of Geological Sciences from samples collected by Messrs. S.W. Hester and A. Morter in September 1964 when a new carriage-way on the A2 was under construction near Cobham, Kent.(I.G.S. sample numbers JL 856-JL 942). The section shown in Figure 2.5 was copied from the I.G.S. Sample Register but, as there is no record of the exact height above base of each sample collected, only their approximate positions within each bed can be shown.

SECTION FROM SOUTH SIDE OF CARRIAGE-WAY.

WOOLWICH AND READING BEDS.

Woolwich Shell Beds.

Bed 8.

JL 942* Silty clay, dark yellowish brown, 10YR4/2, with abundant shell fragments.

JL 937* Silt, light olive grey, 5Y6/1, with clay lenses, moderate yellowish brown, 10YR5/4, with abundant shell fragments.

JL 936+ Sand, moderate yellowish brown, 10YR5/4, with abundant shell fragments.

JL 934+ Silty clay, moderate yellowish brown, 10YR5/4, with abundant shell fragments.

Bed 7.

JL 933+ Clay, light olive grey, 5Y6/1, with sand lenses, pale greenish yellow, 10Y8/2, iron-stained, with some very small gypsum crystals.

JL 932 Fine sand, light olive grey, 5Y7/2, iron-stained.

JL 931* Fine silty sand, light grey, N7, iron-stained on fracture planes, with a few shell fragments.

Bed 6.

JL 912* Siltstone, light brown, 5YR5/6, with many shell fragments.

Bed 5.

JL 910* (5E) Lightly consolidated sandstone, pale yellowish brown, 10YR6/2, with abundant shell fragments.

JL 909 (5D) Clay, brownish black, 5YR2/1, iron-stained, with some shells and abundant gypsum.

JL 905* (5D) Laminated clay, dusky yellowish brown, 10YR2/2, iron-stained, with abundant shells and some gypsum.

JL 901 (5D) Laminated clay, dark grey, N3, with lenses of sand, moderate yellowish brown, 10YR5/4, with common Corbicula spp., some gypsum.

JL 898* (5D) Clay, dark grey, N3, with abundant shells including Corbicula sp., iron-stained, some gypsum.

JL 895 (5D) Clay, greyish black, N2, with silt lenses, moderate yellowish brown, 10YR5/4, shells and much gypsum.

Woolwich Shell Beds.

Bed 5. continued

JL 892 (5D) Laminated clay, greyish black, N2, and moderate yellowish brown, 10YR5/4, with some shells and gypsum.

JL 889 (5C) Clay, greyish black, N2, with abundant bivalves and gastropods, some gypsum.

JL 887* (5C) Shelly clay, greyish black, N2, and moderate yellowish brown, 10YR5/4, some gypsum.

JL 885* (5B) Laminated silty clay, greyish black, N2, with lenses of silt, moderate yellowish brown, 10YR5/4, many shells, Corbicula sp., iron-stained, some gysum.

JL 884 (5B) Laminated silty clay, brownish black, 5YR2/1, with many shells and much gypsum, iron-stained.

JL 883* (5A) Shelly clay, moderate yellowish brown, 10YR5/2, with lenses of glauconitic sand, dusky yellow 5Y6/4; carbonaceous partings.

Lignite Bed 4.

JL 867* (4D) Lignite, black, N1, dull, blocky fracture, some woody structure visible; gypsum present.

JL 866* (4C) Lignite, greyish black, N2, and brownish black, 5YR2/1, friable, dusty, with blocky fracture.

JL 865* (4B) Lignite, brownish black, 5YR2/1, friable, dusty with blocky fracture. Some patches of sand, gypsum present.

JL 864* (4A) Lignite, brownish black 5YR2/1, friable, very dusty with silty laminae, light brownish grey, 5YR6/1, some gypsum present.

Woolwich Bottom Bed

Bed 3.

JL 863+ Poorly sorted glauconitic sand, light olive 10YR5/2, with some shells.

JL 860+ Poorly sorted glauconitic sand, light olive 10YR5/2.

Bed 2.

JL 858+ Sandstone, moderate yellowish brown, 10YR5/4, with many well-rounded black flint pebbles, up to 1cm.long.

JL 856+ Glauconitic fine silty sandstone, light greenish grey, 5GY8/1.

SECTION FROM NORTH SIDE OF ROAD.

WOOLWICH AND READING BEDS.

Lignite.

JL 880+ Lignite, olive black, 5Y2/1, massive, with clear cellular structure on some surfaces, dusty, blocky fractures, shiney on broken surfaces.

JL 879* Lignite, black, N1, massive, dusty, clearly laminated with small patches of ?sand and gypsum. Woody cellular structure in places.

WOOLWICH AND READING BEDS.

Lignite, continued

JL 877+ Lignite, black, N1, massive, shiney on fractures, faint lamellar structure.

JL 874+ Lignite, greyish black, N2, massive, dull, shiney on fractures, weak lamellar structure.

JL 871+ Lignite, greyish black, N2, with dull and shiney laminae, dull layers predominate. Cellular structure visible on some surfaces.

JL 869+ Lignite, black, N1, massive, well laminated, shiney and dull layers (0.25mm), shiney conchoidal fractures.

5. SWANSCOMBE; Northfleet Quarry, Kent (TQ 598730)

WOOLWICH AND READING BEDS. (Composite Section)

Woolwich Shell Beds.

SW 38 * (4.16m above lignitic horizon). Laminated clay, medium dark grey, N4, and fine sand, yellowish grey, 5Y8/1.

SW 37 * (3.65m). Silty clay, greenish grey, 5GY6/1, with abundant shell fragments.

SW 36 (3.30m). Clay, medium greenish grey, 5GY5/1, with many shell fragments and much fine gypsum.

SW 35 (3.28m). Clay, medium greenish grey, 5GY5/1, with many shells, gastropods and molluscs.

SW 34 (3.20m). Clay, medium olive grey, 5Y5/1, with many shell fragments and small gypsum crystals.

SW 33 * (2.74m "Marl" horizon). Very calcareous siltstone, moderate brown, 5YR4/4, with molluscs, very small gastropods less than 2mm long and very rare ostracods (unidentified).

SW 32 (2.44m). Clay, medium grey, N5, with partings of fine sand, yellowish grey 5Y8/1, with molluscs and very small (2mm) gastropods.

SW 31 (2.13m). Silty clay, medium olive grey, 5Y5/1, with abundant shells, molluscs and gastropods.

SW 30 * (1.83m). Silty clay, moderate olive grey, 5Y5/1, with abundant gastropods and with lenses of fine sand, yellowish grey, 5Y8/1. Much gypsum present.

SW 29 (1.52m). Laminated silty clay, light olive grey, 5Y6/2, and fine sand, yellowish grey, 5Y7/2. Gastropods and bivalves present; much gypsum. Bioturbated.

SW 28 (1.22m). Silty clay, medium olive grey, 5Y5/1, with lenses of fine sand, yellowish grey, 5Y8/1; rare very small shell fragments; bioturbated.

SW 27 (1.07m-1.02m). Silty clay, brownish grey, 5YR5/1, with lenses of fine sand, yellowish grey, 5Y8/1; some shell fragments and much gypsum.

SW 26 * (0.76m). Silty clay, dark yellowish brown, 10YR4/2 and olive grey 5Y4/1; lenses of fine sand; many mollusc shells.

SW 25 (0.46m). Sand, moderate yellowish brown, 10YR5/4, with abundant shell fragments.

SW 24 (6.15m). Lightly cemented sandstone, pale yellowish brown, 10YR7/2, to brownish grey, 5YR/1, with shell fragments (oysters).

SW 23 * (Lignitic horizon). Sand, ironstained, pale greyish orange pink 5YR7/1, with lignitic clasts, thin lenses (2mm) of medium grey clay with shell fragments.

6. SOUTH LAMBETH ROAD BOREHOLES. (TQ 304772)

BOREHOLE 8.

LONDON CLAY.

SL 42 * (7.16m below surface) Clay, moderate yellowish brown 10YR5/2, with very small shell fragments and gypsum.
SL 43 (9.14m) Clay, pale yellowish brown, 10YR6/2, with small carbonaceous fragments.
SL 44 * (12.19m) Silty clay, light olive grey, 5Y6/1, with very fine gypsum and black mineral streaks.
SL 45 (15.24m) Silty clay, moderate yellowish brown, 10YR5/2, with small gypsum crystals.
SL 46 * (18.29m) Silty clay, pale yellowish brown, 10YR6/2, with gypsum and small carbonaceous fragments.
SL 47 (21.34m) Silty clay, light olive grey 5Y6/1, with very fine carbonaceous fragments and gypsum.
SL 48 * (24.38m) Silty clay, light olive grey, 5Y6/1, with gypsum and black ?mineral streaks.
SL 49 (26.97m) Clayey silt, light brownish grey, 5Y6/1, with small carbonaceous fragments and many small gypsum crystals.
SL 50 * (30.48m) Clayey silt, moderate yellowish brown, 10YR5/2, with much gypsum.
SL 51 * (33.53m) Fissile clay, light olive grey, 5Y6/1, with abundant gypsum and small carbonaceous fragments.

WOOLWICH AND READING BEDS.

Mottled clay.

SL 1 * (38.71-39.17m. below surface) Mottled, soapy clay, light greenish grey, 5G8/1, moderate yellowish brown, 10YR5/4.
SL 2 (39.17m) Mottled, soapy clay, greenish grey, 5GY6/1 and light olive grey, 5Y6/1.
SL 3 (39.62m) Mottled soapy clay, light greenish grey, 5G8/1, yellowish brown, 10YR6/4 and dark reddish brown, 10R3/4.
SL 4 (40.70m) Mottled clay, moderate brown, 10YR5/4 and light greenish grey, 5G8/1.
SL 5 (41.15m) Mottled silty clay, moderate yellowish brown, 10YR5/4 and light greenish grey, 5G8/1.

?Striped Loams.

SL 6 * (42.22m) Laminated clay, dusky yellowish brown, 10YR2/2 with carbonaceous partings and silt, yellowish grey, 5Y8/1, bioturbated.
SL 7 (42.67m) Sand, yellowish grey, 5Y8/1, with silty layers, olive black, 5Y2/1 and carbonaceous partings.

SOUTH LAMBETH ROAD, BOREHOLE 8 continued.

Woolwich Shell Bed.

SL 8 (43.28m) Fine sand, light olive grey, 5Y6/1, with small shell fragments.
SL 9 (43.74m) Laminated silty clay, olive grey, 5Y4/1, and light olive grey 5Y6/1, with shell fragments.
SL 10 * (44.20m) Silty clay, light olive grey, 5Y6/1, with many shells.

Mottled Clay.

SL 11 + (45.26m) Mottled silty clay, pale olive 10Y6/2, moderate yellow, 5Y7/6 pale red, 5R6/2 and white, N9.
SL 12 (45.42m) Marl, white, N9; pale red, 5R6/2; light olive grey, 5Y6/1 and light olive brown, 5Y5/6.
SL 13 (45.72m) Mottled clay, pale greenish yellow, 10Y8/2, pale red 5R6/2 and dark reddish brown, 10R3/4.
SL 14 (46.79m) Mottled clay, light greenish grey, 5G8/1, pale red, 5R6/2 and dark yellowish orange, 10YR6/6.
SL 15 (47.24m) Mottled silty clay, moderate yellowish brown, 10YR5/4, dark yellowish orange, 10YR6/6 and light greenish grey, 5G8/1.

Pebble Bed.

SL 16 (49.38m) Mottled sandstone, moderate yellowish brown, 10YR5/4, moderate greenish yellow, 10Y7/4 and greyish red, 10R4/2, with well - rounded flint pebbles.
SL 17 (49.99-50.29m) Mottled sandy clay, moderate yellowish brown, 10YR5/4 and dark reddish brown, 10R3/4, with many flint pebbles.
SL 18 (50.44m) Mottled sandy clay, moderate yellowish brown, 10YR5/4, moderate greenish yellow, 10Y7/4 and dark reddish brown, 10R3/4, with many pebbles.
SL 19 * (50.9m) Sandstone, greyish olive, 10Y4/2 are moderate brown, 5YR4/4, with many flint pebbles.

THANET BEDS.

SL 20 (51.82-52.12m below surface) Glauconitic sand, light olive grey, 5Y5/2.
SL 21 * (53.04m) Glauconitic silty sand, moderate olive brown, 5Y4/4 with some shell fragments.
SL 22 + (53.34-53.57m) Glauconitic silty sand, moderate olive brown, 5Y4/4, with clay lenses, pale olive 10Y6/2.
SL 23 (54.25m) Glauconitic sand, light olive grey, 5Y5/2.

THANET BEDS continued.

SL 24 + (54.86-55.09m) Fine silty sand, light olive grey, 5Y6/1.
SL 25 + (55.78m) Sand, light olive grey, 5Y5/2.
SL 26 + (56.39-56.59m) Fine silty sand, light olive grey, 5Y6/1.
SL 27 * (57.3m) Fine silty sand, light olive grey, 5Y5/2.
SL 28 + (57.91-58.14m) Fine silty sand, light olive grey, 5Y5/2.
SL 29 * (58.83m) Sand, olive grey, 5Y4/1.
SL 30 + (59.44-59.74m) Fine silty sand, light olive grey 5Y5/2.
SL 31 * (60.96-61.19m) Silty sand, dark yellowish brown, 10YR4/2.
SL 32 (62.48-62.64m) Silty sand, dark yellowish brown, 10YR4/2.

BOREHOLE 13.

WOOLWICH AND READING BEDS.

Upper Shell Bed.

SL 40 * (36.58-37.08m below surface) Fissile silty clay, medium olive grey, 5Y5/1, with some broken shells and very small charcoal fragments.

Lower Shell Bed.

SL 41 * (43.89-44.35m) Laminated silty clay, light olive grey, 5Y6/1, with many shell fragments.

7. LEADEN RODING BOREHOLES (TL 594136) (Samples from the Essex River Authority).

BOREHOLE 1.

LONDON CLAY.

LR 1 (41.15m below surface) Silty clay, light olive grey, 5Y6/1, with very small gypsum crystals and many assorted pebbles, up to 5mm. long.
LR 2 (42.67m) Silty clay, moderate yellowish brown, 10YR5/2, many pebbles up to 4mm long, abundant gypsum.
LR 3 * (44.20m) Silty clay, moderate yellowish brown, 10YR5/2, with small pebbles and much gypsum.
LR 4 (45.72m) Silty clay, light olive grey, 5Y6/1, with pebbles up to 1cm. long and small gypsum crystals.
LR 5 (47.24m) Silty clay, medium olive grey, 5Y5/1, with many pebbles, and London Clay conretions about 2.5cm. long, very calcareous. Much gypsum.
LR 6 (48.77m) Silty clay, light brownish grey, 5YR6/1, with small pebbles and much gypsum.
LR 7 * (50.29m) Silty clay, light brownish grey, 5YR6/1, with small pebbles and much gypsum.
LR 8 (51.82m) Silty clay, light brownish grey, 5YR6/1, with gypsum and small carbonaceous fragments.
LR 9 (53.34m) Silty clay, light brownish grey, 5YR6/1, with much gypsum.
LR 10 * (54.86m) Silty clay, dark yellowish brown, 10YR4/2.
LR 11 (56.39m) Silty clay, medium olive grey, 5Y5/1.
LR 12 (59.91m) Silty clay, olive grey, 5Y4/1.
LR 13 (59.44m) Clay, medium olive grey, 5Y5/1.
LR 14 * (60.96m) Silty clay, olive grey, 5Y4/1, and light olive grey, 5Y6/1, with a few small pebbles; calcareous.
LR 15 (62.48m) Silty clay, pale yellowish brown, 10YR5/2, with small pebbles up to 3mm. long, some gypsum.

WOOLWICH AND READING BEDS.

LR 16 (64.01m) Fine sand, yellowish grey, 5Y8/1, with streaks of clay, light olive grey, 5Y6/1, calcareous.
LR 17 * (65.53m) Silty clay, light olive grey, 5Y6/2, with patches of fine sand, pale greenish yellow 10Y8/2.
LR 18 (67.06m) Sandy clay, light olive grey, 5Y5/2, with flint pebbles up to 11mm.
LR 22 * (68.58) Silty clay, moderate yellowish brown, 10YR5/2, with some rounded flint pebbles up to 4mm. long.
LR 23 (70.10m) Clay, light olive grey, 5Y7/1.
LR 24 * (71.02m) Silty sand, greyish brown, 5YR3/3.
LR 25 (71.63m) Very fine sandstone, mottled dark reddish brown, 10R3/4, and dusky yellow, 5Y6/4, with many pebbles.

WOOLWICH AND READING BEDS continued.

LR 26 (73.15m) Sandstone, mottled, moderate brown, 5YR3/4, dusky yellow 5Y6/4, and greyish yellow green 5GY7/2, with small pebbles and shell fragments.

THANET BEDS.

LR 19 (74.68m) Fine sand, yellowish grey, 5Y7/2.
LR 20 (76.20m) Fine sand, light olive grey, 5Y6/1.
LR 21 (77.72m) Glauconitic fine to medium sand, light olive grey, 5Y6/1, with small charcoal fragments.

BOREHOLE 2.

WOOLWICH AND READING BEDS.

LR 27 + (71.63m below surface) Sandstone, moderate reddish brown, 10R4/4, and dusky yellow, 5Y6/4, with silty sandstone, pale yellowish brown, 10YR2/2 and flint pebbles.
LR 28 (73.15m) Silty sandstone, mottled, moderate yellowish brown, 10YR/4, pale olive, 10Y6/2, and moderate brown, 5YR3/4, with small flint pebbles up to 1.5cm. long.

THANET BEDS.

LR 29 + (74.68m) Glauconitic silty sand, light olive brown, 5Y5/4.
LR 30 (76.20m) Glauconitic fine sand, olive grey, 5Y6/2.
LR 31 + (77.72m) Glauconitic fine sand, light olive grey, 5Y6/1, with some gypsum.
LR 32 (79.25m) Glauconitic fine sand, light olive grey, 5Y5/2.
LR 33 (80.77m) Glauconitic fine sand, light olive grey, 5Y5/2.
LR 34 * (82.30m) Glauconitic fine sand, moderate olive brown, 5Y4/2.
LR 35 (83.82m) Glauconitic silty sand, light olive grey, 5Y5/2.
LR 36 * (85.34m) Glauconitic silty sand, medium olive grey 5Y5/1, with gypsum.
LR 37 + (86.87m) Glauconitic fine sand, light olive grey, 5Y5/2, light olive grey, 5Y6/1, and dusky yellow, 5Y6/4.
LR 38 * (88.39m) Silty sand, dark yellowish brown, 10YR4/2, and dusky yellowish brown, 10YR2/2, with gypsum.
LR 39 + (89.92m) Sandy silt, dark yellowish brown, 10YR4/2, with very small gypsum crystals.

Bullhead Bed.

LR 40 (91.44m) Glauconitic silty sand, olive grey 5Y3/2, and pale olive, 10Y6/2, with large flint pebbles, 2cm. long and cobbles of chalk, up to 7.5cm.

8. PINCENTS KILN. (SU 653722)

SECTION A. Not shown on Figure 2.9, near to Section 1.

READING BEDS

PK 6 * (1.83m above Chalk) Clay, brownish grey, 5YR4/1, with leaf impressions.
PK 5 * (1.68m) Clay, brownish grey, 5YR6/1; with sandy lenses, pinkish grey, 5YR8/1, with charcoal steaks.
PK 4 * (1.68m) Clay, brownish grey, 5YR6/1.
PK 3 + (0.91m) Clay, medium dark grey, N4, with lenses of coarse, glauconitic sand, dusky yellow green 5GY5/2.
PK 2 + (0.61m) Glauconitic fine sand with silt partings, greenish grey, 5GY6/1.
PK 1 + (0.08-0.15m) Coarse glauconitic sand, greyish olive green, 5GY3/2, pebbles of chalk and flint.

SECTION 1.

READING BEDS.

PK 25 (2.31-2.24m above Chalk) Silt, light olive grey, 5Y7/1. Iron-stained.
PK 24 * (2.11-2.03m) Silty sand with a few sand patches, light brownish grey 5YR6/1, with some carbonaceous fragments.
PK 23 * (1.82m-1.90m) Laminated clay, medium grey N5, with lenses of silt, light greenish grey, 5GY8/1, and white sand, occasional charcoal fragments. Iron-stained.
PK 22 (1.80-1.72m) Silty clay, medium light grey, N6, with lenses of silt, yellowish grey, 5Y8/1, occasional charcoal fragments and much gypsum.
PK 21 * (1.57-1.49m) Wavy bedded silty clay, light brownish grey, 5YR6/1, with irregular patches of silt and sand, yellowish grey 5Y8/1, occasional leaf impressions.
PK 20 * (1.42-1.34m) Sand, light brownish grey, 5YR6/1, with irregular carbonaceous patches and charcoal fragments.
PK 19 * (1.19-1.14m) Wavy bedded clay with silt layers, light brownish grey, 5YR7/1. Iron-stained.
PK 18 * (0.91-0.84m) Clay, olive grey, 5Y4/1, with lenses of fine sand, greyish yellow, 5Y8/4. Iron-stained.
PK 17 * (0.81-0.71m) Clay, medium grey, N5, with silt patches, yellowish grey, 5Y8/1.
PK 16 + (0.71-0.66m) Wavy bedded clay, medium greenish grey, 5GY6/1, with silt lenses, light greenish grey, 5GY8/1.
PK 15 + (0.58m) Glauconitic sand, greyish green, 10GY5/2, with occasional laminae of glaucontic clay, greenish grey, 5GY6/1.
PK 14 (0.55-0.50m) Glauconitic sand, pale yellowish green, 10GY8/1, with clay lenses, yellowish grey, 5Y7/2 and flint pebbles about 2mm long.

SECTION 1.

READING BEDS. continued.

PK 13 * (0.35-0.30m) Glauconitic sand, light greenish grey, 5G8/1.

PK 12 * (0.20-0.15m) Glauconitic sand with flint pebbles, light greenish grey, 5G8/1.

PK 11 + (0.05m) Glauconitic sand, greyish green, 10YR6/6, iron-stained, with chalk fragments and flint pebbles.

PK 10 + (base) Chalk, white, N9, with borings filled with glauconitic sand, greenish black, 5G2/1, and glauconitic clay, light olive grey, 5Y5/2.

SECTION 2.

READING BEDS.

PK 35 * (4.0-3.96m above Chalk) Silty clay, light brownish grey, 5YR6/1, with small carbonaceous fragments and occasional leaf impressions.

PK 34 * (2.44-2.38m) Clay, very light grey N8, with lenses of silty clay, light brownish grey, 5YR7/1 and sand, yellowish grey, 5Y8/1; abundant impressions of dicotyledonous leaves.

PK 33 (2.0-1.95m) Laminated silty clay, light brownish grey, 5YR7/1, with lenses of sand, pale yellowish brown, 10YR6/2, with occasional fragmentary leaf impressions.

PK 32 (1.65-1.6m) Silty clay, light grey, N7, interbedded with sandy silt, pale yellowish brown, 10YR6/2, with abundant fragmentary leaf impressions.

PK 31 + (1.27-1.22m) Glauconitic sandy silt, light grey, N7, with lenses of glauconitic sand, light greenish grey, 5G8/1, iron-stained.

PK 30 + (1.16-1.12m) Silty clay, light grey, N7, with lenses of silt, white, N9, with occasional leaf impressions.

PK 29 * (1.12-1.06m) Laminated silty clay, light grey, N7, with silt partings, very light grey, N8.

PK 28 + (0.76-0.71m) Wavy bedded silty clay, light olive grey, 5Y6/1, with silt partings, yellowish grey 5Y8/1, iron-stained.

PK 27 (0.66-0.58m) Glauconitic sand, greyish olive green 5GY3/2, with clay lenses, yellowish grey 5Y8/1, and flint pebbles. Iron-stained.

PK 26 + (0.20-0.15m) Glauconitic sand with clay lenses, yellowish grey, 5Y8/1, and large pebbles of flint and chalk.

9. M4 MOTORWAY, VARIOUS EXPOSURES IN READING BEDS.

Furze Hill: SU 512740, Sand pit west of the bridge.

M4/1 + Bulk "channel" sample, 19cm thick. Laminated silty clay, yellowish grey 5Y8/1 and medium grey, N5, with lenses of unsorted silty sand, yellowish grey, 5Y8/1 and leaf impressions c.14-15.25cm from base.

M4/2: SU 499741, Sand pit north of carriage-way.

M4/2a+ Silty clay, yellowish grey, 5Y7/2, some contamination from recent roots.
M4/2b+ Unsorted sandy silt, light olive grey, 5Y6/1, with rare charcoal clasts and sandy patches, dark yellowish orange, 10YR6/6, ?bioturbated.
M4/2c Interbedded coarse sand (grains fairly well rounded), pale yellowish brown, 10YR6/2 and unsorted silty sand, yellowish grey, 5Y8/1.

Coombe Wood: SU 551737, Southern side of carriage-way.

M4/3c+ Silt, yellowish grey 5Y8/1, with rare small charcoal clasts. From a lense within main sand body c.3m below mottled clay.
M4/3b Mottled silty clay, dusky red, 5R3/4 and brownish grey, 5YR4/1.
M4/3a Mottled clay, micaceous, yellowish grey, 5Y7/2, moderate yellowish brown, 10YR5/4 and dusky red 5R3/4. From c.0.3m above base of mottled clay unit.

Bussock Wood: SU 467728. Drainage trench in centre of carriage-way.

M4/5(8)+(45cm above Chalk) Glauconitic silty sand with silt lenses, greenish grey 5GY6/1, bioturbated.
M4/5(7) (42cm) Poorly sorted, glauconitic silty sand, light olive grey, 5Y6/2.
M4/5(6) (38cm) Laminated silty clay, light olive grey, 5Y6/1 with lenses of glauconitic sand.
M4/5(5)+(20cm) Silty, glauconitic sand, greenish grey 5GY6/1. (Matrix of flint pebble bed).
M4/5(3) (2cm) Clay, light olive grey, 5Y6/1 and glauconitic sand, light olive grey, 5Y5/2. Many small chalk pebbles.
M4/5(2) (2cm; lateral equivalent of M4/5(3)) as above.
M4/5(1) (2cm; lateral equivalent of M4/5(2) and (3)). Laminated clay, dusky yellow, 5Y6/4, with chalk fragments.

HEWINS WOOD: SU 601738. Northern side of motorway, about 0.25 km north of Hewins Wood.

M4/7(4) * (3m above Chalk) Laminated silty clay, light olive grey 5Y6/1, leaf impressions.

M4/7(3) * (2m) Silty clay, medium olive grey 5Y5/1 and fine sand, yellowish grey, 5Y8/1. Leaf impressions.

M4/7(2) * (50cm) Micaceous, silty sand, moderate yellowish brown, 10YR5/1.

M4/7(1) * (18cm) Ostrea bellovacina Bed. Unsorted glauconitic, silty sand, light olive grey, 5Y5/2, abundant oysters.

10. WATERLOO KILN, Reading.

WK + Matrix from sample of Reading Leaf Bed, B.M.N.H. sample V. 56968. Sandy silt, pale yellowish brown, 10YR7/1.

11. KNOWL HILL SAND PIT: SU 819798

KH * Laminated silt, yellowish grey 5Y7/2 and sand, light olive grey, 5Y6/1 with leaf impressions. (Sample collected by Mr. R. Ashfield 1960).

12. COLD ASH QUARRY, near Newbury, Berkshire: SU 501713

NB 1 * (Lens A within Reading Beds sand, c.7.5m above Chalk). Silty claystone, light olive grey, 5Y6/1, partings with abundant, broken, large leaves, most with carbonised cuticle present.

NB 2 * (Lens A within Reading Bed sand, c.7.5m above Chalk, lateral equivalent of NB 1). Silty claystone, yellowish grey 5Y7/2, with leaf impressions and occasional leaf remains.

13. ALUM BAY. Isle of Wight (SZ 305853).

Spot samples collected on the Geologists' Association Field Trip, May 1974 led by Messrs. A. and C. King. Samples taken as examples of the Division A-C of the London Clay Formation recognised by Mr. C. King (see King 1981, Fig. 31).

BRACKLESHAM BEDS (sensu Eaton 1976).

AB 70 * Leaf Bed (? = Fisher Bed 8) Clay, light brownish grey, 5YR6/1, with fragmentary, carbonaceous leaf impressions.
AB 68 * (? = base Fisher Bed 4) Silty sand, medium grey, N5, with more silty lenses.

Bed 2 (Eaton 1976).

AB 64 * Poorly sorted silty sand, yellowish grey, 5Y8/1, with silty partings, brownish grey, 5YR4/1, and common fragmentary lignite, probably transported.
AB 63 * Poorly sorted sand, yellowish grey, 5Y8/1, with some charcoal, and abundant lignite, probably transported.
AB 62 Silty claystone with sand lenses, medium olive grey, 5Y5/1, bioturbated.
AB 61 Poorly sorted, glauconitic, silty sand, light olive grey, 5Y6/1, with laminae of sandy silt, olive grey 5Y4/1.
AB 60 * Silty claystone, medium olive grey, 5Y5/1.
AB 59 Very poorly sorted silty sand, light olive grey, 5Y6/1, with some glauconite.

Bed 1 (Eaton 1976).

AB 57 * (From channel into underlying sand). Unsorted silty sand, pale yellowish brown, 10YR6/2, with lignite fragments.

LONDON CLAY FORMATION.

Division C. (King 1981).

AB 58 * Silty clay, medium brownish grey, 5YR5/1, with carbonaceous patches.
AB 56 * Fine silty sand, moderate yellowish brown, 10YR5/2, with molluscs, Glycimeris sp.

Division B2. (King 1981).

AB 55 * Silty clay, medium olive grey, 5Y5/1, with silty sand partings, yellowish grey, 5Y8/1, Gypsum present.
AB 54 * Glauconitic silty sand, pinkish grey, 5YR8/1, interbedded with silty clay, medium olive grey, 5Y5/1.
AB 53 (Pinna horizon). Silty clay, moderate yellowish brown, 10YR5/2, with charcoal fragments and common bivalves, Pinna sp.

Division B2 continued.

AB 52 * (Shell horizon). Silty clay, moderate yellowish brown, 10YR5/2, with small, fragmentary bivalves and gastropods.
AB 51 Silty clay, moderate yellowish brown, 10YR5/2.

Division B1. (King 1981).

AB 50 * (A level with diverse small bivalves and molluscs. Planktonic Foraminiferid marker of Wright 1972). Silty clay, moderate yellowish brown, 10YR5/2, with some mica and rare, small gastropods.

Division A3. (King 1981).

AB 49 * (Top of Division A3, horizon with gastropods and Turritella). Poorly sorted, glauconitic, sandy silt, moderate yellowish brown, 10YR5/2.
AB 48 Siltstone, moderate yellowish brown, 10YR5/2.
AB 47 * (Astarte horizon near base of Division A3). Silty clay, medium brownish grey, 5YR5/1, with molluscs, including Astarte.
AB 46 (Nodular horizon). Unsorted, glauconitic, silty sand, moderate yellowish brown, with clay pellets.

OLDHAVEN FORMATION. (King 1981).

AB 45 * (Tilehurst Member). Cross-bedded, glauconitic, poorly sorted fine sand, light olive grey, 5Y6/1.

READING BEDS.

AB 44 + (c.70cm below pebble bed at base of Oldhaven Formation). Silty clay, mottled yellowish grey, 5Y6/1 and moderate yellowish brown, 10YR5/4.
AB 43 + Silty clay, pinkish grey, 5YR8/1.
AB 42 + Mottled clay, light olive grey, 5Y6/1 and moderate red, 5R4/6.
AB 41 + (from fissure in Chalk). Sandy clay, N7, light grey, with some fragments of Chalk, white, N9.
AB 40 + (from solution hollow in Chalk). Poorly sorted silty sand, pale yellowish brown, 10YR6/2.

APPENDIX 2:

PERCENTAGE OCCURRENCE OF PALYNOMORPHS IN PALAEOCENE AND EARLY EOCENE SECTIONS FROM SOUTHERN ENGLAND.

Table A2.1, A2.2	Pegwell Bay, Oldhave Gap.
Table A2.3, A2.4	Charlton, Swanscombe, Shorne Wood.
Table A2.5, A2.6	Leaden Roding, South Lambeth Road,
Table A2.7, A2.8	Cold Ash Quarry, Waterloo Kiln, Knowl Hill M4 Motorway, Pincents Kiln.
Table A2.9, A2.10	Alum Bay.

KEY

(R)	reworked.
0.4	% occurrence.
+	species present but % occurrence not recorded.
*	less than 250 spores/pollen counted.

TABLE A2.1 PERCENTAGE OCCURRENCE OF SPORES AND POLLEN IN PALAEOCENE AND EARLY EOCENE SECTIONS AT PEGWELL BAY AND OLDHAVEN GAP.

		PEGWELL BAY										
		CLIFFS END SECTION							CAR PARK SECTION			
		Thanet Beds										
		Bullhead Bed	Greensand Bed		Stourmouth Clays			Pegwell Marls		Reculver Silt		
		PB1	PB3	PB5	PB8	PB10	PB11	PB12	PB13	PB16	PB18	
Smooth trilete spores	1								8.4	2.8	3.6	1
Baculatisporites comaumensis	2											2
Camarozonosporites sp.	3									+		3
Cicatricosisporites dorogensis	4											4
Cicatricosisporites spp.	5								0.4			5
Contignisporites problematicus	6								+			6
Coronatispora valdensis (R)	7							+				7
Densoisporites velatus	8						+		+			8
Densosporites sp. (R)	9								+	0.4	+	9
Gleicheniidites senonicus	10						+		0.4	0.4	0.4	10
Ischyosporites sp.	11								0.4			11
Kraeuselisporites reissingeri (R)	12											12
Leiotriletes sp.	13			+						3.2	1.6	13
Lycopodiumsporites clavatoides (R)	14						+	+				14
Lycopodiumsporites spp.	15											15
Lycospora sp. (R)	16											16
Osmundacidites spp.	17											17
Pilosisporites trichopapillosus (R)	18											18
Stereisporites sp.	19							+		0.4		19
?Tegumentisporis sp.	20											20
Trilobosporites spp. (R)	21											21
Trilete spores (undifferentiated)	22	0.4	1.0	3.2	2.8	1.2	3.6	8.0	3.6	2.8	1.6	22
Laevigatosporites discordatus	23										0.4	23
Laevigatosporites haardti	24	0.8		0.4		0.8		1.2	0.4	0.8	0.4	24
Verrucatosporites favus	25							+				25
Monolete spores (ornamented)	26									0.8		26
Callialasporites dampieri (R)	27			0.4			+	+		1.2	+	27
Callialasporites spp. (R)	28				1.2	0.8	1.2	1.2				28
Inaperturopollenites turbatus (R)	29								0.4			29
Cerebropollenites mesozoicus (R)	30			0.4	+	+	+	+	1.6	1.6	0.8	30
Florinites sp. (R)	31											31
Bisaccate pollen undifferentiated	32	8.0	18.0	20.0	15.6	18.0	30.0	9.6	26.4	34.0	50.4	32
Parvisaccites radiatus (R)	33								0.4			33
Podocarpidites spp. (R)	34			0.8								34
Quadraeculina anellaeformis (R)	35								+			35
Vitreisporites pallidus (R)	36	0.4				0.8	0.4					36
Araucariacites australis	37	0.4										37
Inaperturopollenites hiatus	38	18.4	25.0	17.2	23.6	10.0	9.6	33.6	1.2	4.0	0.8	38
Inaperturopollenites polyformosus	39											39
Inaperturopollenites spp.	40	16.0	22.5	15.2	13.2	17.6	9.6	1.6	1.6	0.8	1.6	40
?Perinopollenites elatoides	41	0.8	1.5	1.2	3.2	3.6	2.0	+	2.0	0.4	0.8	41
Spheripollenites group	42			0.8	0.4	2.0	3.2	+	1.2	0.4	0.4	42
Classopollis torosus	43			0.4		1.2	5.6	2.8	15.2	2.8	3.2	43
Chasmatosporites spp. (R)	44						+	+	1.6			44
Clavatipollenites spp.	45											45
Liliacidites spp.	46							+				46
Milfordia incerta	47										0.8	47
Monocolpopollenites tranquillus	48					1.6	0.8		+			48
Monocolpopollenites spp.	49	0.8	1.0	3.6	2.0	2.0	3.2	2.8	1.2		0.4	49
Cornaceoipollenites parmularius	50						0.4					50
liblarensis/microhenrici group	51	4.4	3.5	3.2	0.8	1.2	1.6	4.0				51
Cupuliferoidaepollenites cf. liblarensis	52	5.6	1.0	1.6	2.0	1.6	1.2	+		0.4		52
Fraxinopollis variabilis	53		1.5	6.0	7.2	7.2	3.6	8.4	1.6	1.2	0.8	53
Retitrescolpites anguloluminosus	54	1.2	1.5	0.4		0.4	2.0	+	0.4	0.8	0.8	54
Tricolpites parvus	55	0.4		1.6	2.8	6.8	2.4	8.4	6.0	8.0	4.0	55
Tricolpites sp. A	56									0.4		56
Tricolpopollenites retiformis	57	2.0	4.5	2.8	1.6	2.8	2.8		1.2	1.2		57
Tricolpate pollen undifferentiated	58	2.0	2.5	1.6	1.2	3.2	2.8	3.2	2.4	3.6	1.2	58
Brevicolpate/colporate pollen	59											59
Favitricolporites baculoferus	60											60

OLDHAVEN GAP

		Thanet Beds					Woolwich Beds			Oldhaven Beds	London Clay		
	OG28	OG1	OG2	OG3	OG5	OG7	OG9	OG11	OG12	OG14	OG27	OG25	OG26	
1	1.2	+	+	2.4	1.2	0.4					4.0			1
2					0.8						+			2
3				0.8										3
4					0.4									4
5				+	0.4						0.4			5
6											+			6
7	0.4													7
8											0.4			8
9											+			9
10						+			+				0.4	10
11											+			11
12											+			12
13		+												13
14				1.2							+			14
15			+											15
16				+		+	+				0.8	+		16
17					+	0.4	+							17
18							+							18
19				0.8	0.8									19
20				+		0.8								20
21								+			+			21
22	0.8	2.0	3.6	0.4	1.2	0.4	4.4	1.2	2.0		3.2	0.8		22
23						0.4		+			0.4			23
24	0.4	1.2		0.4	0.4	0.4	1.2	1.6	0.8		1.2	+	0.8	24
25											0.4			25
26			0.4			+					0.4			26
27					+	+			0.4		0.4	+	+	27
28		+					1.6	0.8						28
29		+		0.4			+	+			+	+		29
30			0.4		0.8	0.4	0.4	+	0.8		2.0			30
31						+								31
32	2.8	6.4	12.8	5.2	7.6	7.2	6.4	7.2	3.2	+	13.6	16.0	12.8	32
33					0.8		+				0.4			33
34			0.4				+				0.4			34
35											+			35
36	0.4					0.4	0.8				1.2		0.4	36
37											0.4			37
38	7.6	27.6	28.4	24.4	27.2	22.8	28.0	14.0	8.0		13.6	6.8	10.4	38
39			1.6	4.4	6.4	3.6			1.2		1.2			39
40	9.6	8.0	8.8	2.4	7.2	7.2	8.8	0.4	1.6		8.0	4.8	9.6	40
41	1.6	2.0	1.2	0.4	1.6	0.8	1.6	1.6			5.2			41
42		+		+		+	+		0.4		2.0			42
43	1.2	+	0.8	1.2	1.6	1.2	0.8	1.6	3.2		7.2	+	1.6	43
44											1.2			44
45									+					45
46	1.2	0.8	1.2	+					+			0.4		46
47													0.8	47
48	0.4	2.4		0.8			1.6	3.6	+			1.2	0.8	48
49	0.4	2.0	0.4	2.8	0.4		2.4	1.6	0.4		1.6	1.2	2.0	49
50								+						50
51	1.6	+	0.8	1.6	2.0	2.0	0.4	2.4	4.0		0.8	0.4	2.8	51
52	2.8	0.8	0.4	2.0	0.4	+	3.6	1.6	0.4			0.8	0.4	52
53	6.8	2.8	3.2	10.4	3.6	3.6	3.6	10.8	11.6		2.4	4.4	2.4	53
54	0.4	0.4	0.4	+		+	0.4	1.2	0.4			0.4		54
55	21.2	14.0	6.8	8.4	7.2	10.8	9.6	10.4	6.0		7.2	1.6	1.2	55
56									0.4					56
57	1.2	0.8	3.2	0.4	0.4	2.0	3.2	3.6	1.2		1.2	6.8	3.6	57
58	6.0	0.4	4.8	2.0	3.2	5.2	3.2	6.0	8.8		4.0	5.2	4.4	58
59	0.4			+	+		+					0.4		59
60	0.4		0.4					+	0.4		+		+	60

TABLE A2.1 continued

	PB1	PB3*	PB5	PB8	PB10	PB11	PB12	PB13	PB16	PB18	
Margocolporites lihokus	61										61
Nyssapollenites spp.	62								0.4	0.4	62
Pentapollenites sp.	63							0.4	0.4	0.8	63
Spinaepollis spinosus	64			0.4					0.4		64
?Spinulaepollis sp.	65	0.4									65
Striate tricolpate/tricolporate pollen	66					+					66
Tricolporopollenites aceroides	67										67
T. cingulum	68			1.2		0.4	3.2		0.4	0.4	68
T. duplibaculatus	69										69
T. iliacus	70										70
T. kruschi	71			0.4			+				71
T. margaritatus	72									0.4	72
T. megaexactus	73		0.4	0.8		1.2	+				73
T. megareticulus	74		0.4								74
T. salardae	75	0.4			1.6						75
T. cf. sittleri	76				0.8						76
Tricolporopollenites spp.	77			6.4	0.4	3.2	2.8	0.4	1.2	0.4	77
Cupanieidites spp.	78				0.4						78
Duplopollis golzowensis	79										79
Polycolpites sp.	80							0.4		0.4	80
Tetracolporopollenites spp.	81										81
Ericipites sp.	82					0.4					82
Pandaniidites texus	83										83
Restioniidites minimus	84										84
R. hungaricus	85								0.4	0.4	85
S. sparganioides	86										86
Sparganiaceaepollenites spp.	87										87
Basopollis orthobasalis	88										88
Caryapollenites spp.	89					0.4		0.4		0.4	89
Compositoipollenites rhizophorus	90								0.4	0.4	90
C. minimus	91							0.4	0.8	0.4	91
?Compositoipollenites sp.	92				0.4						92
Normapolles undifferentiated	93		0.4					0.8	0.4	0.4	93
Gallopollis minimus	94	0.5			0.4						94
Intratriporopollenites microreticulatus	95									0.4	95
I. pseudinstructus	96					0.4	0.8				96
Intratriporopollenites spp.	97										97
Labrapollis labraferus	98										98
M. tenuipolus/M. coryloides	99	0.4	0.8		0.8		+		1.2		99
M. rotundus	100										100
Nudopollis endangulatus/terminalis	101	2.8	0.5					2.0	2.4	0.8	101
Platycaryapollenites platycaryoides	102	4.8	2.5	3.2	4.0	4.0	2.4	2.0	1.2	4.8	0.8	102
Plicapollis pseudoexcelsus	103	12.4	1.0	1.6	1.2	1.6	0.8	0.8	3.2	2.0	6.8	103
Plicatopollis spp.	104		1.0		0.4	0.8		+	0.4	0.4		104
Pompeckjoidaepollenites subhercynicus	105			0.4					0.4			105
Subtriporopollenites anulatus	106											106
S. anulatus subsp. nanus	107									0.4	+	107
S. constans subsp. constans	108								1.2			108
S. constans subsp. magnus	109											109
S. intrastructurus	110	0.4	0.5		+	1.2						110
Subtriporopollenites spp.	111											111
Triatriopollenites confusus	112	0.8	0.5	0.4					0.4			112
T. roboratus	113			0.4					+	0.4	1.6	113
T. subtriangulus	114										0.4	114
Triatriopollenites/Momipites group	115	4.8	5.0	1.2	3.2	3.2	0.4	2.0	3.2	4.0	4.4	115
Triporopollenites plektosus	116	0.8	0.5				0.4				0.4	116
T. robustus	117		0.5	1.6	0.4	0.4	0.4		2.0	1.6	2.0	117
Triporopollenites spp.	118	7.2	1.0	3.2	1.6	0.8	1.6	0.4	3.2	1.6	2.4	118
Trivestibulopollenites spp.	119								+			119
Trudopollis hammenii	120			0.4			0.8		+		0.4	120
Vacuopollis spp.	121		0.5	0.4			0.4					121
Alnipollenites trina	122			0.4		+						122
A. verus	123	0.4	0.5	0.8		0.4	+			1.6		123
Erdtmanipollis spp.	124											124
Interpollis messelensis	125											125
I. supplingensis	126				0.8					0.4	0.4	126
Panporate pollen undifferentiated	127											127
Reevsiapollis triangulus	128											128
S. hexaradiatus subsp. semitribinae	129						0.4	0.4				129
S. hexaradiatus subsp. tribinae	130						+			0.4		130
Ulmipollenites tricostatus	131	2.8	2.0				0.4			0.4		131
Ulmipollenites spp.	132			2.0	1.6			+	0.4	1.2	0.4	132
Interporopollenites laevigatus	133								0.8			133
Others	134			1.2				2.4	0.8		+	134

	OG28	OG1	OG2	OG3	OG5	OG7	OG9	OG11	OG12	OG14	OG27	OG25	OG26	
61				0.4										61
62	0.8	0.8	0.4	0.8		1.2	0.8		0.4					62
63	0.4					+			+				+	63
64				+					+					64
65						0.4			0.4					65
66														66
67		0.4					+							67
68	10.0	4.8	1.2	4.4	5.6	4.4	2.4	0.8	2.0		2.0	0.8	0.8	68
69				0.4				+			+			69
70			0.4										+	70
71								+						71
72				+					+				+	72
73	0.8	6.4	3.6	0.4	0.8	2.0	0.4	0.4					1.2	73
74												0.4		74
75					0.4			+				+	+	75
76	0.4		0.4			0.4								76
77	3.2	6.4	4.0	7.2	5.2	7.2	1.6	3.2	1.6		4.4	1.2	1.2	77
78		0.8												78
79						+								79
80									1.2					80
81								+						81
82			+					+	+					82
83								+					0.4	83
84				+					+		+			84
85							0.4	0.4				0.8		85
86											0.4			86
87				+			0.4					0.4		87
88		0.8						+						88
89				0.4		0.4	0.4	0.8	+		+	0.4	0.4	89
90	0.4				+	+	0.8	0.4	1.6		+			90
91	0.4							+			+			91
92	0.4												0.4	92
93		+		0.4		0.4		1.2	0.4			0.4		93
94		+	0.4	0.4			1.6	1.2	1.6			0.8		94
95				+	+	0.4	+	+			0.4		+	95
96							0.4		0.4		1.2		0.4	96
97					+	0.4		1.2	0.4		0.4	0.4	0.4	97
98						0.8	0.4						+	98
99	1.6	1.2		+	0.8	0.8	+	4.8	0.8					99
100	0.4		0.4		0.4	0.8		+	2.8		0.4	2.0	1.6	100
101	0.4	0.4		+			+	+	0.4	+			+	101
102	1.6	2.4	2.4	2.4	0.4	0.8	2.8	3.6	2.8		0.8	6.0	11.6	102
103	0.8	+	0.8	0.4	0.4	+	1.2	+	4.4	+		9.2	3.6	103
104	0.4			+	1.2	+	+	0.4	0.8		0.4	3.2	1.2	104
105		+						+	+					105
106							+	0.4						106
107					0.4	+			+			0.4		107
108														108
109							0.4						0.4	109
110												0.8	2.0	110
111	0.4	0.4				0.4						0.4		111
112	1.2		0.4		+	0.4		+	0.8	+		0.4		112
113						+	+					+		113
114	0.4			0.4		+			+		+			114
115	4.8	0.8	2.0	2.8	3.6	5.2	0.4	2.0	10.4		2.0	10.4	6.4	115
116		0.4	0.4		0.4			2.0	0.4			1.2	1.2	116
117	0.8	+	1.2	0.4	+	0.4	+	+	3.6			1.6	0.8	117
118	1.2	0.8	1.6	2.4	0.8	1.2	1.2	3.6	3.2	+	1.6	3.2	5.6	118
119									0.4					119
120		+				+								120
121				0.4	0.4	+		+						121
122														122
123		0.8		+		+	0.8	1.2	1.6			0.8	0.4	123
124								0.4						124
125								0.4			0.4	+	0.4	125
126						+			0.4			+	0.4	126
127							0.4							127
128													0.4	128
129														129
130														130
131	0.4	+	0.4	2.0	2.8	2.0		0.8	1.2		+	3.2	2.0	131
132		+			0.4		0.8		0.4			0.4		132
133														133
134		0.8		1.2	0.4		0.4	1.2	0.4		0.4		0.8	134

TABLE A2.2 PERCENTAGE OCCURRENCE OF MICROPLANKTON AND OTHER ALGAE IN PALAEOCENE AND EARLY EOCENE SECTIONS AT PEGWELL BAY AND OLDHAVEN GAP.

		PEGWELL BAY										
		CLIFFS END SECTION						CAR PARK SECTION				
		Thanet Beds										
		Bullhead Bed	Greensand Bed		Stourmouth Clays			Pegwell Marls		Reculver Silt		
		PB1	PB3	PB5	PB8	PB10	PB11	PB12	PB13	PB16	PB18	
DINOFLAGELLATE CYSTS												
Achomosphaera alcicornu	1								+	3.0	1.0	1
Achomosphaera spp.	2				0.8		+	+	1.1		1.6	2
Alisocysta margarita	3	0.2	0.2	0.9	1.9		4.2	1.6	+	+	+	3
Apectodinium homomorphum	4											4
A. parvum	5											5
Apectodinium spp.	6								+			6
Areoligera/Glaphrocysta	7	17.8	47.4	11.3	12.5	5.5	18.3	51.2	10.3	19.7	35.4	7
Areoligera senonensis/coronata	8	+			+			+	20.9	16.6	5.9	8
Areoligera spp.	9									1.4	3.7	9
Chorate cysts undifferentiated	10				10.7		12.7	10.0			0.5	10
Cleistosphaeridium group	11	2.4	3.5	13.7	14.2		4.2		2.2	1.5	3.2	11
Cordosphaeridium fibrospinosum	12										2.7	12
C. inodes	13							+	+	+	+	13
Cordosphaeridium spp.	14	0.8	0.2	2.4	1.9			+	1.1	3.7	2.8	14
Deflandrea dartmooria sl.	15		+	+					6.6	5.3	11.8	15
D. denticulata subsp. minor	16							+				16
Deflandrea spp.	17	1.8	3.5	13.8	2.2	4.5	5.6	4.4	+	0.7		17
Diphyes colligerum	18											18
Glaphrocysta divaricatum	19								+	+	+	19
G. exuberans	20									1.6		20
G. ordinatum	21								+	5.3		21
Glaphrocysta spp.	22										+	22
Gonyaulacysta jurassica (R)	23											23
Gonyaulacysta sp.	24											24
Hafniasphaera spp.	25				+			+	+		1.0	25
Homotryblium pallidum	26										+	26
Hystrichokolpoma mentitum	27				0.5			+				27
Hystrichosphaeridium patulum	28											28
H. tubiferum	29		0.9		+			+	3.3	0.7	2.7	29
Hystrichosphaeridium spp.	30											30
Inversidinium exilimurum	31	0.4		+						0.7		31
Lingulodinium machaerophorum	32											32
?Microdinium sp. 2 S.-L. & Ch.	33	1.8	2.4	7.9	8.8	1.8		2.4	1.1		+	33
aff. ?Microdinium sp.2	34		2.4						4.4		1.0	34
Microdinium sp.	35											35
Nannoceratopsis gracilis (R)	36											36
Oligosphaeridium complex	37	0.2	+									37
Operculodinium centrocarpum	38							+			+	38
Palaeostomocystis laevigata	39	10.9	11.9	4.4	6.9	6.4	+		15.4	0.7		39
Pareodinia ceratophora (R)	40											40
Sentusidinium spp. (?R)	41							+		3.0	2.7	41
Spiniferites cingulatus	42											42
S. comutus	43											43
S. ramosus	44				+		+	+				44
S. pseudofurcatus	45							+	+		+	45
Spiniferites spp.	46	0.4	2.0	4.4	+		+	+	6.6	3.7	10.2	46
Trigonopyxidia ginella (?R)	47				+							47
Phthanoperidinium crenulatum	48							+		6.8	0.5	48
Dinoflagellates undifferentiated	49	0.8	4.5	4.4	18.6	2.7	5.6	2.4	2.2	4.5		49
ACRITARCHS												
Comasphaeridium cometes	50	2.6	3.7	3.9	6.7	3.7	4.2	7.0	1.1	0.7		50
Cymatiosphaera spp.	51	2.8	0.2	3.9	0.7	6.4	5.6	+	3.3	1.5	0.5	51
Horologinella spp.	52	0.2	1.2	0.5	4.0	2.7	1.4	+				52
Leiospheres	53	23.3	7.3	7.9	3.0	18.3	5.6	6.0	3.3	0.7	0.5	53
Micrhystridium spp.	54	27.8	8.1	14.8	5.6	40.3	25.3	1.0	14.3	12.8	3.8	54
Veryhachium spp.	55	2.6		0.5			1.4					55
Acritarchs undifferentiated	56	0.8	0.2	4.4			5.6	14.0				56
OTHER ALGAE												
Crassosphaera sp.	57					0.9			1.1	1.5		57
Tasmanites sp.	58											58
Paralecaniella indentata	59	0.6						+	1.1	1.5	7.5	59
Pediastrum	60											60
Pterospermella spp.	61	1.2	0.2	0.9	0.9	6.4				1.5	1.0	61
?Ovoidites sp.	62									0.7		62
Botryococcus	63						+	+	+	+		63
Total microplankton		491	402	202	708	109	72	250	91	132	186	

OLDHAVEN GAP

	Thanet Beds						Woolwich Beds			Oldhaven Beds		London Clay		
	OG28	OG1	OG2	OG3	OG5	OG7	OG9	OG11	OG12	OG14	OG27	OG25	OG26	
1					+									1
2				2.3					+		2.7			2
3														3
4											2.7			4
5											2.7			5
6											2.7			6
7				2.3	3.5			15.8						7
8			+		+	+								8
9		2.4			3.5		3.7	+		14.2				9
10		7.1					6.4	11.0						10
11		10.3	15.8	6.9		7.2	9.2		3.5	7.1	2.7	1.4		11
12						+								12
13					+	+					+			13
14	+			2.3	3.	3.6		+	+		2.7			14
15	+					+	0.5	1.5			+			15
16														16
17		3.6	2.1	2.3	+	1.8	0.5		10.6	7.1	+		+	17
18						+								18
19														19
20					+									20
21						+				+				21
22		+	8.5		5.1		5.0	+	+	7.1	+			22
23											+			23
24										7.1	+			24
25		+	1.1	+							2.7			25
26														26
27														27
28				2.3										28
29					+									29
30	2.3		1.1		+									30
31														31
32					+									32
33														33
34				2.3	+	+								34
35											2.7			35
36											+			36
37														37
38	2.3			+	1.7	+				+				38
39														39
40											+			40
41	2.3			4.6	5.1	+		+	3.5		10.8	+	+	41
42						+								42
43					+									43
44			13.8	2.3	8.6	3.6	+				2.7			44
45	.													45
46				2.3	1.7									46
47	+													47
48	11.6													48
49	2.3	8.3	8.5		5.1	5.4	13.9	11.0			10.8	4.1		49
50	4.6	+	4.2	4.6	5.1	9.1	+				+	8.2	4.4	50
51	6.9	4.7	5.3	6.9		9.1	7.5	17.3	21.4	+		9.6	3.3	51
52	4.6		1.1	2.3		3.6	0.5						6.6	52
53	16.2	22.6	8.5			1.8	1.6	3.0	3.5		10.8	2.7	3.3	53
54	44.1	38.0	28.6	53.3	49.8	52.7	48.6	38.0	53.4	14.2	37.8	63.0	76.9	54
55	2.3						1.0		3.5			1.4	1.1	55
56							1.0			35.7	2.7	2.8	2.2	56
57				2.3		1.8		+				+	2.2	57
58												+		58
59		2.4	1.1		6.8	+		1.5		7.1	2.7			59
60		+											+	60
61	+	+		+			+					5.5	+	61
62														62
63						+					+	+	+	63
	43	84	94	43	56	54	188	63	28	14	37	74	60	

TABLE A2.3 PERCENTAGE OCCURRENCE OF SPORES AND POLLEN IN PALAEOCENE SECTIONS AT CHARLTON, SHORNE WOOD AND SWANSCOMBE.

CHARLTON

		Woolwich & Reading Beds									
		Bottom Bed			Shell Beds					Striped Loams	
		CH1	CH2	CH4	CH5	CH6	CH9	CH8	CH11	CH12	
Trilete spores undifferentiated	1	4.0	1.6			0.8	3.6		2.4	2.0	1
Smooth trilete spores	2	0.8	4.4	0.8	2.4	1.2			+	2.8	2
Appendicisporites sp.	3	+									3
Baculatisporites/Osmundacidites spp.	4	0.4								+	4
Cicatricosisporites dorogensis	5					0.4		+			5
C. paradorogensis	6									0.8	6
Densoisporites velatus	7									+	7
Densoisporites sp.	8	+	0.4								8
Gleicheniidites senonicus	9								0.4		9
Hydrosporis levis	10										10
Klukisporites spp.	11				0.8	0.4		0.4		0.4	11
Lycopodiumsporites clavatoides	12									+	12
Lycospora sp.	13		1.2			0.4				0.4	13
Pilosisporites sp.	14										14
Polypodiaceoisporites macrospeciosus	15				+	+				+	15
P. cf. marxheimensis	16										16
Stereisporites sp.	17					+					17
?Tegumentisporis sp.	18						+	+	0.4	+	18
Triplanosporites sinuosus	19	+			+	+				+	19
Triquitrites sp.	20		0.4								20
Uvaesporites argenteaformis	21										21
Laevigatosporites discordatus	22			+		+	+			+	22
L. haardti	23			0.4		+	0.4	0.8	1.6	0.8	23
Laevigatosporites spp.	24										24
Ornamented monolete spores	25	+			+		0.4	0.8		0.4	25
Callialasporites dampieri (R)	26		0.4							+	26
Inaperturopollenites turbatus (R)	27		0.4				0.4				27
Cerebropollenites mesozoicus (R)	28	2.0	1.6		0.4		0.4		0.4	+	28
Bisaccate pollen undifferentiated	29	19.6	16.8	0.4	0.4	1.2	1.6		+	1.6	29
Parvisaccites radiatus (R)	30	0.4									30
Striate bisaccate pollen (R)	31										31
Vitreisporites pallidus (R)	32		0.4				0.4			+	32
Araucariacites australis (R)	33		0.8			0.4	+			+	33
Inaperturopollenites hiatus	34	28.0	10.0	7.2	4.0	8.4	9.6	6.0	14.4	9.2	34
I. polyformus	35			1.2	1.2	1.2	+	+		0.4	35
Inaperturopollenites spp.	36	3.2	10.8	5.6	2.4	3.2	2.8	2.8	2.4	8.0	36
?Perinopollenites elatoides	37		+	0.4		+				2.4	37
Spheripollenites group	38	1.6	2.0	0.8			+			0.8	38
Classopollis torosus (R)	39	1.6	2.8	0.4		0.8	+	0.8	0.4	2.8	39
Chasmatosporites spp. (R)	40										40
Clavatipollenites spp.	41		0.8								41
Liliacidites spp.	42		0.4	1.2	0.4	0.4		0.4			42
Milfordia incerta	43										43
Monocolpopollenites tranquillus	44	1.2	0.8	0.4	3.2	6.4	2.4	3.6	2.0	2.8	44
Monocolpollenites spp.	45	0.4	2.0	4.0	3.2	2.0	2.0	2.8	1.2	0.8	45
Disulcites spp.	46				1.2	0.4					46
Cornaeceoipollenites parmularius	47					+	+				47
liblarensis/microhenrici group	48	2.8	1.6	5.2	4.0	3.2	4.8	4.8	3.6	0.8	48
Cupuliferoidaepollenites cf. liblarensis	49	0.8	+	0.8		1.2	1.6	3.2	1.2	0.8	49
Fraxinopollis variabilis	50	5.2	0.4	0.4	2.4	4.0	2.0	7.2	3.2	1.6	50
liblarensis/microhenrici/variabilis gp.	51										51
Retitrescolpites angulolumino sus	52			0.4	0.4	0.8	2.0	0.4	1.2	0.4	52
Tricolpites parvus	53		+			0.8	1.2	1.2	0.8	3.6	53
Tricolpites sp. A	54			+	0.4	0.4	0.8	0.4	0.4	0.4	54
Tricolpites sp. B	55										55
Tricolpites sp. C	56										56
Tricolpopollenites retiformis	57	4.0	3.2	0.8		0.8	0.4	1.2	2.0	2.0	57
Tricolpate pollen undifferentiated	58	2.0	1.6	1.6	2.4	1.2	2.4	3.2	4.0	2.8	58
Aesculiidites circumstriatus	59			+		+	1.2	0.8	0.8	0.8	59
Brevicolpate/colporate pollen	60										60
Favitricolporites baculoferus	61	0.4	0.4			+				0.4	61
Margocolporites lihokus	62										62
Nyssapollenites sp. A	63										63
Nyssapollenites spp.	64		0.4		0.4	+		0.4		+	64
Pentapollenites sp.	65		0.4			0.4				+	65
Rhoipites psinnus	66										66

	CHARLTON						SWANSCOMBE						SHORNE WOOD												
	Woolwich & Reading Beds						Woolwich & Reading Beds						Woolwich & Reading Beds												
	Striped Loams						Lignite	Shell Beds					Lignite					Woolwich Shell Beds							
	CH18	CH15	CH19	CH16	CH17	CH21	SW23	SW26	SW30	SW33	SW37	SW38	JL864	JL865	JL866	JL867	JL879	JL885	JL887	JL905	JL910	JL912	JL931	JL937	JL942
1	0.4		1.6	0.8	2.0	+			0.4	0.4		1.2	1.2	+	0.4	1.6	0.4	3.2	3.2	1.2	3.2	4.4	1.6	1.2	9.2
2	0.4	1.6	1.2		+	+		0.8	0.4	0.8	2.0		+	+		+		+						+	+
3																									
4		+							0.4																
5	+	+	0.4	+	+				0.4	0.4	0.8							+	+		+	+		+	
6	0.4	+		+								+													
7																									
8			+																						
9												0.4													
10														+											
11												0.4										+		+	
12				+								+													
13		+																							
14						+																			
15									+				+	+	+	+									
16	+	+	0.4	+												+									
17																						+			
18	+	+	0.4		+																				
19	+																								
20																									
21										0.4															
22	0.4		+	+					0.4	0.4	+														
23	1.2	1.2	0.8	2.8	1.2				0.4	0.4		1.2													
24													1.2	4.4	+	8.0	0.8	4.0	6.8	2.4	2.8	1.6	1.2	0.4	1.6
25		0.4	0.4				+											+	+	+					
26	+																								0.8
27	+											+													
28	0.4											0.8													
29	1.2	1.2	1.2	0.4	0.4	2.4	+		0.8		0.4	2.0	+	+	+	+	+	+	+	0.4	0.8	0.4	2.4	0.8	
30																									
31	+											+													
32		+		0.4	0.4							0.8													
33																									
34	7.6	9.6	9.2	6.4	10.8	6.8		14.0	19.2	14.0	8.0	16.0					8.0	+	+	0.4	0.4	0.4	8.8	14.8	6.7
35		+		1.2							0.4														
36	6.8	6.4	5.6	4.8	2.4	11.2		0.4	3.2	2.0	1.6	6.0				1.2	2.0	2.0	2.0	2.8	6.0	19.2	1.2		
37	0.4	+				0.4			0.4			0.4		0.4					2.8		1.2	2.0		0.4	0.8
38	2.4	1.2	1.2	0.8	+	0.8												0.8	0.4	1.2					
39	1.2	0.8	0.4	0.4	0.4	+			0.8			+								0.4		0.4	2.0	0.4	
40			0.4									0.4													
41			0.4																						
42	0.4		+	0.4	0.8			1.2	1.6		1.2	0.4						+			+		0.8		
43														+	0.4										
44	2.0	0.8	2.4	4.4	2.8	1.2		3.2	1.6	2.0	0.4	+	13.2	11.6	6.0	+	5.2	11.2	3.2	6.4	4.8	3.2	1.6	2.0	2.5
45	2.0	0.8	1.6	1.6	0.8	2.8	+	1.2	0.8	1.2	0.8	1.2	0.4			0.8		4.4	0.4	2.8	4.4	6.0	0.4	3.2	10.1
46	+	+	0.4			0.4			+			0.4						0.8	+	+		0.4			
47		0.4	+	0.4		+			0.8					+					+						
48	3.6	2.0	2.4	1.6	3.2	0.8		4.4	2.4	2.0	7.6	2.0													
49	0.4	0.8	1.2	0.8		+		0.4	0.4	0.4	2.4		+		+	+				+	+	+	1.2	+	+
50	4.4	5.2	6.4	6.4	4.4	3.2	+	0.4	1.2	2.0	2.4	3.2													
51													6.0	2.0	4.8	7.6	2.0	6.8	4.4	9.2	10.4	10.0	5.6	10.4	9.2
52	2.0	0.4	0.4	0.4	+	1.2		0.4	+			0.8			+			+	+					+	
53	2.8	2.8	1.2	1.2	3.6			0.4	1.6	3.2	2.8	1.2			+			+	+	+	+	+	1.2	+	+
54			+	0.4		+		+			0.4		20.0			1.6		2.0	+		0.4				
55													+	+	0.4					+					
56		0.4																							
57	0.8	1.6	2.0	2.4	3.6	4.0		0.4	1.2	2.0	1.6	2.0	0.8	0.4	+	0.4	1.2	1.2	0.4	1.6	0.8	1.6	4.4	+	
58	2.0	1.6	2.8	3.6	0.4	+		2.4	3.2	4.0	0.8	2.8	0.4	2.8	0.8	1.6	0.4	1.6	2.0	2.0	0.4	2.8	4.4	0.4	
59	1.6	1.2	+	0.8		2.4	+	0.8							+	+		+	+	+	+	+			
60											0.4														
61	0.4	0.4		0.4		+						0.4		+		+		+	+						
62		+																							
63										0.4	0.4							+	+					0.4	
64	1.6	0.8	+	0.4	0.4	+					0.4														
65				+				0.4			+	0.4													
66			+																						

TABLE A2.3 continued

		CH1	CH2	CH4	CH5	CH6	CH9	CH8	CH11	CH12	
Rhoipites sp. A	67									0.4	67
Spinaepollis spinosus	68					+			+		68
?Spinulaepollis sp.	69										69
Striate tricolpate/tricolporate pollen	70		0.4			0.4	0.4	0.4	0.4	+	70
Tricolporopollenites aceroides	71		0.4		0.8	1.2		+	0.4	0.4	71
T. baculatus	72										72
T. cingulum	73	0.4		1.6	8.8	4.8	8.8	9.6	10.0	9.2	73
T. dublibaculatus	74									+	74
T. kruschi	75							0.4		+	75
T. mansfeldensis	76										76
T. margaritatus	77			0.4							77
T. megaexactus	78				+	+	0.8	0.8		+	78
T. megareticulus	79						0.4	0.4	0.4		79
T. salardae	80				1.2	0.8				0.4	80
T. cf. sittleri	81		0.4	0.4	0.4					0.4	81
Tricolporopollenites spp.	82		0.4		1.6	2.0	2.0	2.8	2.4	2.4	82
Cupanieidites spp.	83				+	+				0.4	83
Tetracolporopollenites spp.	84									+	84
Ericipites sp.	85			0.4							85
Pandaniidites texus	86			0.4	0.4	0.8	0.4		0.4	+	86
Restioniidites minimus	87	0.8	+	0.4	0.8	+	0.8		+	0.4	87
R. hungaricus	88			+		1.6	+		0.8		88
Restioniidites spp.	89										89
Sparganiaceaepollenites cuvillieri	90										90
S. cf. cuvillieri	91										91
S. magnoides	92		0.4	+	3.2	0.8	+	0.8	0.4	+	92
S. reticulatus	93				0.4	0.8		+		0.4	93
S. sparganioides	94				1.2		0.4	0.4	1.6	0.4	94
Sparganiaceaepollenites sp. A	95		+								95
Sparganiaceaepollenites spp.	96	0.4	1.2	1.6	1.6	1.6	0.8	0.4	1.2	2.8	96
Basopollis orthobasalis	97										97
Basopollis sp.	98				0.4						98
Caryapollenites spp.	99		+		0.4			0.4		0.4	99
Compositoipollenites rhizophorus ss.	100		0.8			+		0.4			100
C. rhizophorus subsp. burghasungensis	101									0.4	101
C. minimus	102	0.4	0.4	0.4			+	+			102
?Compositoipollenites sp.	103				0.4	0.8	+	0.4	0.8	0.4	103
Normapolles undifferentiated	104			0.4	0.4		0.8		0.4		104
Gallopollis minimus	105	0.4	0.4	1.2	1.2		0.4	1.2	0.8	0.4	105
Intratriporopollenites microreticulatus	106		1.2	0.4	0.4	+				1.2	106
I. pseudinstructus	107		0.4	+	0.8	1.2	0.4	1.2	0.8	0.4	107
Intratriporopollenites sp. A	108		0.4			+		0.4			108
Intratriporopollenites spp. undifferentiated	109	0.8		0.8	0.4	+	0.4	0.8	0.4		109
Labrapollis globosus	110										110
L. labraferus	111			0.8	1.2	0.4	+	0.4	+	+	111
Maceopolipollenites rotundus	112					+		0.4		+	112
M. tenuipolus/Momipites coryloides	113		0.4			0.8	0.4				113
Nudopollis endangulatus/terminalis	114	0.4	+	0.8	0.4	+	0.8	+	0.8	+	114
Pistillipollenites mcgregorii	115				0.4	+		1.2		+	115
Platycaryapollenites anticyclus	116			0.4	0.4	0.8				+	116
P. platycaryoides	117	6.4	6.8	22.8	26.4	24.8	16.8	18.4	20.4	16.0	117
Plicapollis pseudoexcelsus	118	0.4	6.4	6.8	4.4	3.2	1.6	0.8	2.8	1.2	118
Plicatopollis spp.	119	0.4	+	6.8	2.4	2.4	2.0	2.4	3.2	2.0	119
Pompeckjoidaepollenites subhercynicus	120				0.4		0.4				120
Subtriporopollenites anulatus ss.	121					+	+				121
S. anulatus subsp. nanus	122				0.4					+	122
S. constans (sl.)	123				0.4						123
S. intrastructurus	124	0.4	0.4			0.8	3.2	0.8	1.2	1.6	124
S. magnoporatus	125						+				125
S. subporatus	126										126
Subtriporopollenites spp.	127	0.8	+			+				0.4	127
Triatriopollenites confusus	128		2.0	0.4					+	0.4	128
T. roboratus	129	0.4	0.4								129
T. subtriangulus	130									0.4	130
Triatriopollenites spp.	131	2.8	4.4	12.8	3.2	3.6	6.8	8.0	2.4	2.4	131
Triporopollenites plektosus	132	0.8	1.2	0.4		1.2	1.2	1.6	1.2		132
T. robustus	133	0.4		+	+	0.8	1.6	+	0.4	+	133
Triporopollenites spp.	134	1.6	2.0	1.6	0.8	0.8	2.4		2.0	1.6	134
Alnipollenites trina	135	+									135
A. verus	136	1.6	2.0	0.4			0.4			+	136
Interpollis messelensis	137					0.4				0.4	137
I. supplingensis	138		+	1.2		0.4	2.0	1.6	0.8	0.8	138
I. velum	139		+	+	1.6		0.4	0.4	+	+	139
Interpollis spp. undifferentiated	140	0.4	0.4	0.4			0.4	+			140
Pentaporites belgicus	141				0.4			0.4			141
Persicarioipollenites persicarioides	142										142
Reevsiapollis triangulus	143			+						0.4	143
Ulmipollenites tricostatus	144	1.2	0.8	3.6	1.6	2.0	0.8	1.6		0.8	144
Ulmipollenites spp.	145			0.4	0.8				0.8	0.4	145
Others	146	0.4			0.4	0.4	1.6	+		0.4	146

	CH18	CH15	CH19	CH16	CH17	CH21		SW23	SW26	SW30	SW33	SW37	SW38		JL864	JL865	JL866	JL867	JL879	JL885	JL887	JL905	JL910	JL912	JL931	JL937	JL942	
67				+	0.4		67							67														67
68							68							68							+							68
69		0.4					69							69	0.4		+			+								69
70		0.4	+	+		0.8	70							70		+	2.0	0.4	0.4	1.2	0.4	2.4	0.8	2.0		0.8		70
71	+	+	0.4	0.8	0.4		71				1.2	0.4	1.2	71							+	+				+		71
72			+				72							72		+												72
73	12.4	11.2	11.2	7.6	3.2		73		1.2	7.2	6.0	4.8	4.0	73				0.4	0.8	2.4	2.8	5.6	4.8	7.2		8.8	1.6	73
74						0.8	74			+			+	74											+			74
75			+	0.4	+		75		0.4			+		75					+		+							75
76		0.4					76							76														76
77		+		0.8			77				0.4	0.4	0.4	77									+					77
78	0.4		0.4	+	0.4	+	78			1.2	1.6	0.8	0.8	78				0.4	0.4		+		2.4					78
79					+		79							79							+	+			+			79
80	0.8		+	2.0	+		80		0.4	1.2		0.8	2.4	80		+		+				+					+	80
81	0.4	0.4			+	0.4	81		0.8	0.4	0.8		0.8	81	1.2		+	+		+				+	0.8			81
82	2.0	1.2	2.0	4.0	2.0	+	82	+		5.6	4.0	2.8	2.8	82	0.4				1.6	1.2	2.8	0.8	1.2	0.8	0.4	1.2	1.6	82
83	+	0.4			0.8		83					0.8		83						0.8	0.4	0.8	+				3.3	83
84	+			0.4	+		84			0.4				84							+							84
85							85			+			+	85	+	+	+	+		+					0.4			85
86	+	0.4	0.4	+	0.4		86		+					86		+	2.0			0.4	+	0.8		+				86
87		+	0.8	+	2.0		87		0.4	0.4		2.0	0.4	87								0.4			3.2	+		87
88	1.2		0.8	+	+	0.8	88		1.6	1.6	0.8	0.4	0.4	88							+		+	+		+		88
89							89							89			0.4			1.2	+	+	1.6	+		2.8		89
90		0.4					90					0.4		90		+												90
91				0.4			91			0.4				91		+												91
92	0.8	1.2	0.8	0.4	+		92		0.4	1.2	2.0	0.4	0.8	92		+												92
93	+	+	+	0.4	+		93		0.8	0.4	0.8	+	2.4	93		+	+	+		+	+		+	+		+	+	93
94	+	0.8	+	+	+		94					1.2	0.4	94	+	+	+	6.0		+	+	+						94
95					+		95		0.4			0.8		95				+	+		+							95
96	3.2	3.2	1.6		6.0	0.4	96		1.2	0.4	0.4	2.0		96	1.2	3.6	33.2	25.2	13.6	2.0	4.4	2.0	3.6	1.6	1.2	3.2	2.5	96
97							97							97	+		+					0.4		0.4				97
98							98							98														98
99	0.8	0.8	0.4	0.4	+	2.4	99		+	0.4	+	0.4		99		+		+	+	+	+	0.4	+		0.4	+		99
100	0.4	+				0.4	100			+	0.4		0.4	100		+					+							100
101	+						101			+				101			+											101
102	+	+		+	+	0.4	102				0.4		0.4	102														102
103	+	0.8	+	+		0.4	103			+	1.2	0.4	+	103		0.4		+	0.4		+	0.8			0.8	0.8	1.6	103
104		0.4	0.4			2.0	104	+		0.8				104	4.0	+	15.6	14.8	9.2	3.6	6.4	4.0	5.2	3.2	10.0	6.0	0.8	104
105	+	+	0.8	0.8	0.8	1.6	105			0.4	2.4	1.2	3.2	105	9.6	2.0	7.6	8.0	6.0	2.4	3.2	2.8	1.6	2.0	4.8	2.8	0.8	105
106	1.6	0.8	0.4	0.4			106			+	+	0.4	+	106						+	+	+		+		+		106
107	+	0.8	0.4	+	0.4		107		+				0.8	107		+	+	+			+	+	+	+	2.0			107
108	0.4	1.2		0.4		+	108			+	+		+	108	+	+	+			+	+			+		+		108
109	+	0.4	0.8		+	0.4	109			0.4		0.4	0.4	109		0.4	1.6	+		+	1.6	0.4	0.4	1.2		0.8	0.8	109
110					+	+	110				+		0.4	110														110
111	1.2	0.4	0.4		0.8	+	111							111	0.4	0.4					+	0.4	0.4			0.4		111
112			0.4			0.4	112		+	0.4		+	+	112				+										112
113		+	0.8		0.8	+	113			+		+	0.4	113														113
114			+			+	114	+	0.8					114														114
115	+	+	0.4	+	+	0.4	115		+	+		0.8		115	1.2	5.2	1.2	0.8	4.4	0.8	0.4	0.8	0.4	+		0.4	0.8	115
116			1.2			+	116					0.4		116														116
117	16.8	22.8	12.4	14.4	33.2	17.2	117	+	32.8	16.8	29.6	23.6	17.6	117	37.6	62.4	16.0	10.0	36.8	42.4	35.6	36.0	33.6	23.2	30.0	26.4	39.5	117
118	2.0	0.4	1.2	1.2	1.2	0.8	118	+	10.4	5.2	0.8	0.4	2.0	118														118
119	2.4	1.2	4.8	4.0		3.2	119		1.2	1.2	0.4	6.0		119			+				0.4		2.0	0.4	0.8	0.8	0.8	119
120							120				+			120		0.4	0.4	+		+	0.4	+	0.8		0.4			120
121							121							121				+										121
122	+		+				122							122	+	+				+	+		+			+		122
123	+	+			+		123			0.4		+		123	+	+	+	0.4	0.4	+	+			+		+		123
124	+	1.2	0.8	1.2	2.8	1.2	124			+	0.8	1.6	0.8	124	0.4	+	+				+	+	+			+	+	124
125	+	0.4					125			0.4				125		+												125
126							126							126		+										+		126
127						1.2	127							127	+	+	0.8	+	0.4	0.4	0.4	0.4	0.8	+		0.8		127
128	+	+	0.4	0.4	+	+	128	+		0.8			0.4	128							0.4		+			+		128
129							129							129	+	+	+		0.4	+	+					+		129
130	0.4	+				+	130					0.4		130														130
131	2.8	4.0	8.0	8.8	1.2	4.0	131		4.8	2.8	3.6	5.2	0.4	131			0.8	2.4	1.6	0.8	1.6	0.4	0.8	1.6	3.2		1.6	131
132	0.4	0.8	0.4	0.8	0.8	4.0	132		0.8	0.8	0.8	0.8	+	132		2.4	+		2.0	+	+	3.6			1.2	+	0.8	132
133	+	0.8	0.4	0.4	+		133			2.0	+	+	1.2	133	0.4		2.0	+	0.8	+	7.6	2.0	0.8	0.8	0.4	1.6	+	133
134	+		0.4	1.2	1.2	10.8	134	+	4.8	1.6	2.0	1.2	2.0	134		0.8	3.2	3.2	0.8	1.6	4.0	0.8	2.0	1.6	2.4	3.2		134
135						+	135					+		135														135
136						0.4	136		+			+	0.4	136				0.4										136
137		+				0.4	137		0.4	0.4	0.8	0.4		137	+			+		+	+	+	+			+		137
138	1.6	0.4	0.4	2.0	0.4	1.6	138		0.4	+	1.2	0.4	+	138			+	+	+		+	+	+	+		+	0.8	138
139	0.4	+	+	+	0.4		139		0.8		0.4	0.4		139	+			0.4		+	+		+			+		139
140							140							140							1.6	2.4	0.8	+		1.2		140
141				+			141							141							+							141
142							142							142							+							142
143	+		0.4	+			143							143				+										143
144	0.8	0.4	1.2	3.2	1.6	+	144	+	2.0	2.8	0.8	2.4	4.4	144				+		+	+	+	+	+	0.8	+		144
145						5.6	145		2.0					145		+	0.4	4.4		0.8	+	0.8	0.4	0.4	+	2.4	0.8	145
146					1.2	0.8	146		0.4	0.4	0.4	0.4	4.0	146										1.2			0.8	146

TABLE A2.4 PERCENTAGE OCCURRENCE OF MICROPLANKTON AND OTHER ALGAE IN PALAEOCENE SECTIONS AT CHARLTON, SHORNE WOOD AND SWANSCOMBE.

CHARLTON

	Woolwich and Reading Beds									
	Bottom Bed			Shell Beds					Striped Loams	
	CH1	CH2	CH4	CH5	CH6	CH9	CH8	CH11	CH12	
DINOFLAGELLATE CYSTS										
? Adnatosphaeridium patulum			1.2			0.5		1.6		1
Apectodinium homomorphum			7.1	13.0	17.3	2.7	7.6	4.3	5.2	2
A. quinquelatum										3
A. hyperacanthum			2.4				+			4
A. parvum			4.8	3.7	2.6	2.1	+	14.0	5.2	5
Apectodinium spp.			22.6	27.7	8.0	21.6		3.2	25.0	6
Areoligera/Glaphrocysta group	9.2	2.1			9.3	2.6		3.2	1.0	7
Cleistosphaeridium group			17.8	7.4	17.1	5.8	23.0	8.0	1.0	8
Cordosphaeridium fibrospinosum										9
Cordosphaeridium spp.	2.3	+	1.2	1.8	+					10
Deflandrea dartmooria sl.	2.3									11
Deflandrea sp. A		8.5			1.3			5.4	16.6	12
Deflandrea spp.		+				+	7.6			13
Diphyes colligerum			1.2		1.3	0.5			1.0	14
Glaphrocysta ordinata					+					15
Glaphrocysta spp.										16
Homotryblium spp.										17
Homotryblium pallidum			+	5.5						18
Hystrichosphaeridium spp.										19
Leptodinium mirabile (R)						+				20
Lingulodinium machaerophorum										21
? Microdinium sp. 2 Sch.–L. & Ch.	4.6									22
Nannoceratopsis gracilis (R)										23
N. pellucida (R)	2.3									24
Oligosphaeridium complex			1.2						+	25
Operculodinium centrocarpum			+	+	+			+	+	26
Palaeostomocystis laevigata		+			+					27
Sentusidinium spp. (?R)		2.1								28
Spiniferites ramosus		+	8.3	3.7	6.7	5.9			2.0	29
Spiniferites spp.	25.5	+								30
Stephanelytron sp. (R)										31
? Trichodinium group			2.4	22.2	12.0	29.7	46.4	42.7	31.0	32
Tubidermodinium sp.									+	33
Dinoflagellates undifferentiated	6.9	8.5	7.1	3.7	3.9	9.9		2.6	3.0	34
ACRITARCHS										
Baltisphaeridium sp. B Gr.-Cav.			6.0		2.6	+		1.0	+	35
Comasphaeridium cometes	2.3	+	1.2	1.8	+	5.9			1.0	36
Cymatiosphaera spp.	2.3	2.1			1.3	1.0	+	0.5	1.0	37
Horologinella spp.		2.1								38
Large leiospheres										39
Leiospheres	11.4	12.8	8.3	3.7	1.3					40
Mycrhystridium spp.	30.1	57.4	6.0	5.4	9.3	11.7	15.2	13.4	4.0	41
Veryhachium spp.			1.2							42
Acritarchs undifferentiated									2.0	43
OTHER ALGAE										
Crassosphaera sp.										44
Paralecaniella indentata					4.0				1.0	45
Pediastrum sp.					+				+	46
Pterospermella sp.		2.1								47
Ovoidites ligneolus		2.1	+		1.3					48
Schizosporis parvus										49
S. spriggi										50
Tetraporina pellucida										51
Indeterminate Type 1										52
Botryococcus sp.										53
OTHERS	+	+	+	+	+		+		+	
Microforaminiferid linings						+				54
Total microplankton	43	47	84	54	75	185	13	185	96	

	CHARLTON							SWANSCOMBE							SHORNE WOOD											
	Woolwich & Reading Beds							Woolwich & Reading Beds							Woolwich and Reading Beds											
	Striped Loams							Lig-nite	Shell Beds						Lignite					Woolwich Shell Beds						
	CH18	CH15	CH19	CH16	CH17	CH21		SW23	SW26	SW30	SW33	SW37	SW38		JL864	JL865	JL866	JL867	JL879	JL885	JL887	JL905	JL910	JL912	JL931	JL937	JL942	
1	+				+		1			+				1						+								1
2	6.5	7.4	10.7	6.0			2	+		5.4	1.8	7.0	20.4	2						+			+	+	7.1			2
3			0.7				3							3												+		3
4			+				4		3.3	1.8	0.9	1.7		4						+				+				4
5	8.0	9.2	7.7	15.0			5		5.5	0.9	9.0	12.3		5						+				+	3.1			5
6	21.3	42.6	31.7	33.3	72.0		6	1.5	37.7	8.2	8.2	15.8		6						70.3	85.2	23.8	64.3	87.4	11.0	53.6	14.0	6
7			0.7			21.6	7	+	2.2	0.9	+	1.7	2.0	7							1.2		0.8		4.8	+		7
8	1.6		15.4	19.0	7.1	21.9	8	1.0	16.6	25.6	7.3	13.0	4.0	8						3.7	1.2	0.6	3.4	0.3	27.4	12.7		8
9			0.7	1.0	+		9						4.0	9														9
10						1.2	10					1.7		10						+	+		+	+				10
11							11							11														11
12	5.0	1.8	2.3	2.0		+	12						+	12														12
13					4.1		13							13														13
14			0.7	1.0	+	+	14		1.1		0.9			14											0.8			14
15				1.0			15			1.8		0.8		15											+			15
16							16	+					+	16														16
17							17		1.1					17						+			+	+		+		17
18							18							18														18
19							19							19						14.8	3.6	3.2	3.9	0.7	5.5	10.0		19
20							20							20														20
21							21		4.4	11.0		1.7		21											11.0			21
22							22							22														22
23	+						23							23														23
24							24							24														24
25							25							25														25
26	+		+				26	+				+		26											+			26
27							27							27														27
28				+			28							28											2.4	+		28
29	+	1.8	0.7	1.0		+	29		1.1	19.3		2.6	6.1	29									+		+	+		29
30						5.8	30							30											5.5			30
31	+						31							31														31
32	41.0	31.5	12.4	11.1		+	32		9.9	8.2	21.1	28.9	10.2	32						3.7	2.4	2.5	12.6	1.7		4.5		32
33							33							33														33
34			2.3	4.0	4.1	2.4	34	11.0	5.5		0.9	4.4	8.0	34							3.6	2.5	0.8	1.0	7.0	8.2	0.8	34
35			2.3	+		+	35		1.1	1.8	0.9		+	35										+	3.1	+		35
36			3.1	1.0			36				0.9			36														36
37					2.0	4.5	37	0.5	1.1				2.0	37									0.8					37
38							38							38														38
39							39							39			+	+	10.2	1.8		0.6		4.4	2.4	0.9	0.8	39
40	11.5	1.8	3.1	3.0	5.1	4.1	40	53.5	3.3	2.7	7.3		2.0	40									4.4	1.7	0.8	1.8		40
41	5.0	3.7	3.1	+	4.1	37.5	41		4.4	9.1	4.5	3.4	22.4	41							+	1.8	7.8	0.3	7.1	6.2	+	41
42			0.7		1.0		42						12.2	42														42
43							43			2.7	11.9			43									0.4					43
44				+			44							44													0.4	44
45			+				45		1.1					45								+	+			+		45
46	+		0.7	1.0		+	46	0.5			23.8	4.4	6.1	46						3.7		64.7	0.4	2.4		1.8	84.0	46
47						0.8	47	0.5				0.8		47														47
48	+						48	2.5						48		+	+	+		1.8	+							48
49			0.7				49	2.5					+	49	+	50.0	27.3	11.1			2.4							49
50							50	24.5						50	100		72.7	88.8	63.0	+								50
51							51	2.0						51	+	50.0	+	+	25.6									51
52							52							52		+		+										52
53	+		+				53							53							+					+		53
54							54							54														54
	61	54	129	99	97	241		200	90	109	109	114	49		1	2	11	9	39	54	82	159	230	294	127	110	250	

TABLE A2.5 PERCENTAGE OCCURRENCE OF SPORES AND POLLEN IN PALAEOCENE AND EARLY EOCENE SECTIONS AT LEADEN RODING AND SOUTH LAMBETH.

LEADEN RODING

		Thanet Beds			Woolwich & Reading Beds			London Clay				
		LR38	LR36	LR34	LR24	LR22	LR17	LR14	LR10	LR7	LR3	
Trilete spores (undifferentiated)	1	2.0	1.2	0.8		5.2	3.6	8.8	1.6	3.6	6.8	1
Smooth trilete spores (undifferentiated)	2		3.6		+	+					+	2
Baculatisporites/Osmundacidites spp.	3		0.4		+			+				3
Camarozonosporites sp.	4									+		4
Cicatricosisporites dorogensis	5					+						5
C. paradorogensis	6					+						6
Cicatricosisporites spp.	7		+			+						7
Coronatispora valdensis (R)	8											8
Densoisporites velatus	9		0.4					+				9
Densosporites sp. (R)	10											10
Dictyophyllidites harrisi (R)	11		0.4						+	+	+	11
Gleicheniidites senonicus	12		+						+	+	+	12
Klukisporites sp.	13											13
Leptolepidites sp.	14											14
Lycopodiumsporites clavatoides	15		+					+				15
Lycopodiumsporites sp.	16							+				16
Lycospora sp. (R)	17											17
Pilosisporites sp. (R)	18											18
Polypodiaceoisporites macrospeciosus	19											19
P. cf. marxheimensis	20											20
Stereisporites sp.	21										+	21
Taurocusporites sp. (R)	22					+						22
?Tegumentisporis sp.	23					+						23
Trilobosporites sp. (R)	24							+				24
Uvaesporites argenteaformis (R)	25										+	25
Aequitriradites sp. (R)	26											26
Laevigatosporites discordatus	27					0.4		+				27
L. haardti	28	+		0.8		0.8	+	1.6	0.4		0.4	28
Laevigatosporites spp.	29											29
Verrucatosporites favus	30											30
Ornamented monolete spores	31											31
Callialasporites dampieri (R)	32		0.8		+	0.4	+			+		32
Callialasporites trilobatus (R)	33											33
Cerebropollenites mesozoicus (R)	34		1.6	0.4		2.8	0.4	0.8	1.6	1.6	2.8	34
Inaperturopollenites turbatus (R)	35		1.2					+	0.4			35
Bisaccate pollen undifferentiated	36	4.4	10.0	6.4	+	7.2	4.0	5.2	4.0	8.8	12.0	36
Parvisaccites radiatus (R)	37									+	0.4	37
Podocarpidites sp. (?R)	38					0.4				0.4		38
Quadraeculina anellaeformis (R)	39											39
Striate bisaccate pollen (R)	40							+				40
Vitreisporites pallidus (R)	41		0.8		+	0.4	1.6	0.4	0.4	0.8	1.2	41
Araucariacites australis (R)	42		+	0.4						+	+	42
Inaperturopollenites hiatus	43	44.8	10.8	23.2	+	16.4	25.6	18.0	20.4	28.0	14.0	43
Inaperturopollenites polyformosus	44	1.6	2.0		+					+		44
Inaperturopollenites spp.	45	2.4	10.4	1.6	+	6.0	10.0		13.2	9.6	10.0	45
?Perinopollenites elatoides	46		0.8	0.4	+	2.4	3.2	5.2	0.8	3.6	9.2	46
Spheripollenites group	47		0.4	1.2		8.4	9.6	1.6	4.0	7.6	18.0	47
Classopollis torosus (R)	48		0.4		+	2.0	6.0	2.8	2.4	2.4	7.2	48
Rhaetipollis germanicus (R)	49						+					49
Chasmatosporites spp. (R)	50		0.4			+	+	+	0.4			50
Liliacidites spp.	51							+	0.4	0.8	+	51
Milfordia incerta	52		+							0.4		52
Monocolpollenites tranquillus	53			0.4		1.2		0.8			0.4	53
Monocolpopollenites spp.	54		0.8	2.4		0.8	0.4	6.0	4.0	1.2	4.0	54
Ovalipollis ovalis (R)	55											55
Riccisporites tuberculatus (R)	56		0.4				+					56
Disulcites sp.	57						+					57
Cornaceoipollenites parmularius	58											58
liblarensis/microhenrici gp.	59	2.0	1.2	2.0	+	0.8	0.4	0.8	2.0	2.4	0.4	59
Cupuliferoidaepollenites cf. liblarensis	60	0.4		3.2		0.8				0.4	1.2	60
Fraxinopollis variabilis	61	13.2	2.8	5.6		3.6	2.0		2.0	0.8	0.8	61
Retitrescolpites anguloluminosus	62	2.4	0.4	1.6				0.4	1.6	0.4		62
Tricolpites parvus	63	3.2	12.8	10.0		2.8	4.4	4.8	0.8		0.4	63
Tricolpites sp. A	64		0.4				0.4					64
Tricolpopollenites retiformis	65	2.4	1.2	0.4	+	2.0	2.0	0.8	4.0	0.8		65
Tricolpate pollen undifferentiated	66	1.6	6.8	10.4	+	4.0	2.0	2.0	1.2	2.8	1.2	66

SOUTH LAMBETH ROAD BOREHOLES NO. 8 AND NO. 13

	Thanet Beds				Woolwich & Reading Beds						London Clay						
					Borehole No. 8				Borehole No.13								
	SL31	SL29	SL27	SL21	SL19	SL10	SL6	SL1	SL41	SL40	SL51	SL50	SL48	SL46	SL44	SL42	
1	2.8	2.0	0.8	1.2	7.6	2.0	1.2	13.6	1.2	1.6	4.4	2.8	6.4	8.8	8.8	10.4	1
2				0.4		+	+	0.4	+	+	+		+	+		+	2
3												+	+				3
4													+		+		4
5						+		0.4		+			+				5
6																	6
7																	7
8															+		8
9						+							+		+		9
10	0.4			0.4								+		+			10
11			0.4										+	+			11
12	0.4		0.4								0.4						12
13					+					+					+		13
14															+		14
15								+	+		+	+		+	+		15
16											+			+			16
17														+			17
18													+	+			18
19					+	+		+				+				+	19
20							+										20
21	+			0.4										+			21
22																	22
23	+					+											23
24																	24
25																	25
26										+			+				26
27					0.4					+							27
28		0.8	0.8	0.4	2.8	2.0	1.2	+	0.8	2.4		0.4	1.6		4.0	1.6	28
29								14.0									29
30															+		30
31	+	0.4	0.4												0.4		31
32									+	+		0.4			2.8	2.8	32
33		+			0.4										+		33
34	1.6		0.4		0.4		+			+	0.8		0.8	2.8	+	+	34
35	+				0.4		0.4				0.4		+				35
36	8.8	4.4	8.8	7.6	6.4	+	+	+	0.4	1.2	5.2	11.6	11.6	10.8	10.4	10.0	36
37	0.4			1.2			+				0.4		+		+	+	37
38															+	+	38
39														+			39
40																	40
41	0.4				0.4						1.2		+	4.8	1.6	0.8	41
42	0.4			0.4							0.4		+	1.6			42
43	32.0	26.8	34.4	14.0	21.2	10.8	6.8	8.4	8.8	7.6	30.0	19.2	28.0	6.8	23.2	32.4	43
44	0.8	2.4	0.8								1.2						44
45	8.4	5.6	7.6	9.2	0.4				0.4	0.4	8.8	0.4	1.2	20.8	1.6		45
46	4.4	1.6	2.4	1.2	5.6	0.4	0.4		1.2	0.4	3.2	4.8	7.6	3.6	5.6	5.6	46
47	0.4	1.2		0.4	0.8			0.4			0.8	2.0	3.6	12.8	3.6	14.8	47
48	1.6	1.2	1.2	3.2	1.6	+		+	0.4	0.8	6.8	8.4	4.8	7.6	8.0	14.8	48
49											+						49
50						+							+	0.4	+		50
51					1.6	1.2	0.8	1.2		0.8	1.6	1.6	1.6		+		51
52				0.8													52
53				0.4	3.6		0.4	0.8	1.6	4.0	0.4		0.4	1.6	1.2		53
54	+	1.2	1.2	1.2	4.4	5.2	4.0	4.4	6.4	2.0	1.2	2.8	7.6	1.6	4.4	1.2	54
55																+	55
56																+	56
57																	57
58	+	0.8		0.8							0.4				+		58
59	2.4	0.4	1.6	0.4	5.2	6.4	15.2	9.6	7.6	9.6	0.8	7.2	6.8	0.8	4.0	0.4	59
60	+	0.4	0.8	1.6	+	+	+	+	+	+		+					60
61	2.8	6.8	2.8	12.4	+	+	+		+	+	1.6		+		+		61
62		0.8		1.6			0.4		0.4	+		0.8					62
63	6.0	14.8	12.0	1.2	+	+			+	+	0.4	+	+				63
64	1.6	0.8	+						+	1.2					0.8		64
65		2.0	0.8	0.4	2.4	2.4	1.6	6.4	3.2	2.8	2.0	5.2	1.2			0.4	65
66	3.6	2.4	0.8	8.8	0.4	0.4	2.8		0.8	1.6	1.6	2.0	0.4	1.6	2.4	0.4	66

TABLE A2.6 PERCENTAGE OCCURRENCE OF MICROPLANKTON AND OTHER ALGAE IN PALAEOCENE AND EARLY EOCENE SECTIONS AT LEADEN RODING AND SOUTH LAMBETH.

LEADEN RODING

		Thanet Beds			Woolwich & Reading Beds			London Clay				
DINOFLAGELLATE CYSTS		LR38	LR36	LR34	LR24	LR22	LR17	LR14	LR10	LR7	LR3	
Achomosphaera alcicornu	1			+								1
Achomosphaera sp.	2										0.8	2
?Adnatosphaeridium patulum	3											3
Alisocysta sp.	4			2.9								4
Apectodinium homomorphum	5					3.0	+	4.1		+		5
A. parvum	6					+						6
Apectodinium spp.	7											7
Areoligera/Glaphrocysta spp.	8	2.2	4.5	1.4			+	+		0.8	0.4	8
Cordosphaeridium spp.	9	+		2.9			1.0				1.2	9
Cleistosphaeridium group	10	34.4			8.3	21.1	11.0	+	9.5	6.6	12.3	10
Deflandrea dartmooria sl.	11											11
D. phosphoritica	12							+				12
Deflandrea spp.	13								0.9	3.3	0.8	13
Deflandrea sp. A	14											14
Glaphrocysta ordinata	15		4.5				+					15
Glaphrocysta spp.	16											16
Gonyaulacysta dangeardii (R)	17											17
Gonyaulacysta spp.	18		2.3					+		0.8		18
Hafniasphaera spp.	19		2.3					+			+	19
Hystrichokolpoma mentitum	20			+								20
cf. Hystrichosphaeridium patulum	21	1.1										21
H. tubiferum	22		+				+					22
Hystrichosphaeridium group	23	2.2		+						2.5	1.2	23
Inversidinium exilimurum	24											24
Lingulodinium machaerophorum	25					8.3	+					25
Microdinium spp.	26								0.9			26
?Microdinium sp. 2 Sch.-L.&Ch.	27	6.6	+	8.8				2.7				27
aff. ?Microdinium sp. 2	28	4.4										28
Oligosphaeridium complex	29											29
Operculodinium centrocarpum	30						+	+				30
Palaeostomocystis laevigata	31	1.1		+								31
Pareodinia ceratophora (R)	32											32
Sentusidinium spp. (?R)	33	1.1							+	0.8	0.8	33
Spiniferites group	34	5.5	6.8	7.4		3.0	3.0		0.9	3.3	5.6	34
Stephanelytron sp. (R)	35										0.4	35
?Thalassiphora pelagica	36							+				36
?Trichodinium sp.	37				8.3	3.0				2.5	0.8	37
Wanaea digitata (R)	38											38
Wetzeliella spp.	39						+	4.1		+	0.8	39
Undifferentiated chorate cysts	40							6.8				40
Dinoflagellates undifferentiated	41		6.8	2.8		3.0	12.0	29.9	4.6	4.6	5.4	41
ACRITARCHS												
Comasphaeridium cometes	42	1.1				3.0	6.0		15.2	23.3	4.4	42
Cymatiosphaera spp.	43	4.4	6.8	4.4	8.3	6.0	7.0	2.7	1.9	5.0	0.8	43
Hologloginella spp.	44	5.5					2.0	1.3	2.8	2.5		44
Leiospheres	45	4.4	9.0	23.5	8.3	18.1	8.0	16.5	17.1	6.6	25.7	45
Micrhystridium spp.	46	25.4	54.5	44.0	41.6	33.3	42.0	29.9	42.7	28.3	30.8	46
Veryhachium spp.	47					6.0	8.0		2.8	4.1	7.1	47
Acritarchs undifferentiated	48				16.6					5.0		48
OTHER ALGAE												
Crassosphaera sp.	49		+						0.9			49
Botryococcus	50											50
Paralecaniella indentata	51							1.3			0.4	51
Pediastrum sp.	52					+						52
Pterospermella spp.	53		2.3	1.4				+				53
Ovoidites ligneolus	54					+						54
Schizosporis parvus	55							+			0.4	55
Tetraporina pellucida	56											56
OTHERS												
Diatoms (Pyritised)	57								+	+		57
Microforaminiferid linings	58											58
Total microplankton		90	44	68	12	33	100	73	105	120	253	

SOUTH LAMBETH ROAD BOREHOLES NO. 8 AND NO. 13

	Thanet Beds				Woolwich & Reading Beds						London Clay						
					Borehole No.8				Borehole No.13								
	SL31	SL29	SL27	SL21	SL19	SL10	SL6	SL1	SL41	SL40	SL51	SL50	SL48	SL46	SL44	SL42	
1																	1
2	+	+	+														2
3		0.7	0.5														3
4		+	+														4
5								+									5
6																	6
7					39.0	40.6	85.9	+	54.0	26.8							7
8	2.0	5.1	5.0	4.5				18.2		2.4	+		0.9	3.4		6.5	8
9		+	+	2.2							1.2		+				9
10	26.8	14.6	18.4	2.2		9.4	3.8			19.5	13.4			3.4		4.3	10
11	+	0.7	+	+													11
12																	12
13	1.3	3.7	1.0	1.7	+							1.7		+	+	6.5	13
14				3.4													14
15																	15
16		+	+	+													16
17														1.7			17
18																	18
19		+	+														19
20																	20
21																	21
22																	22
23	2.7	2.9	2.0	2.8													23
24	0.7		0.5														24
25																	25
26																	26
27	0.7	+	0.5														27
28	6.1	8.1	2.7														28
29		+	+														29
30																	30
31	1.3	1.4															31
32														3.4			32
33			0.5	0.6							2.4			1.7			33
34	11.4	6.6	5.0	2.8							11.0			8.5			34
35																	35
36			0.5														36
37					10.3	10.4	5.1		7.9								37
38														1.7		2.2	38
39													+				39
40					5.2	2.1						16.9	19.6		11.1	23.9	40
41	4.7	0.7	6.9	3.4	12.9	10.4		9.0	3.0	2.4	2.4	10.1	5.6	18.3	15.5	28.3	41
42	8.8	5.1	12.8	3.4	+						4.9		+	1.7	+		42
43	0.7	16.2		10.0					1.5	2.4	3.7		+	1.7			43
44		0.7	0.5	0.6													44
45	10.8	6.6	8.2	7.3	3.6	19.8			14.2	2.4	9.8	8.4	16.8	7.2	37.6	10.8	45
46	13.6	23.6	30.8	53.0	+	+	+	+			47.5	+	+	41.7	+	+	46
47	0.7							9.0		4.8	2.4		2.8	3.4	4.4	+	47
48					10.3	7.3	5.1	45.5	1.5	17.0	1.2	62.7	53.3	1.7	31.0	17.4	48
49				0.6								+					49
50				+		+							+		+		50
51	6.7	2.9	3.3	1.1		+											51
52					18.2			+	17.5	17.0							52
53	0.7			0.6						2.4			0.9				53
54																	54
55										2.4			+				55
56				0.5													56
57					+						+				+		57
58											+			+	+		58
	148	135	183	179	77	96	78	11	63	41	81	59	107	59	45	46	

TABLE A2.7 PERCENTAGE OCCURRENCE OF SPORES AND POLLEN IN THE PALAEOCENE SECTIONS FROM THE WESTERN END OF THE LONDON BASIN.

		COLD ASH QUARRY		WATERLOO KILN	KNOWL HILL	M4 MOTORWAY				
		Reading Beds								
		NB1	NB2	WK	KH	M4/7 1*	M4/7 2*	M4/7 3*	M4/7 4*	
Smooth trilete spores (undifferentiated)	1			2.4		(1)	(1)		(1)	1
Baculatisporites comaumensis	2									2
Cicatricosisporites spp.	3		+							3
Densoisporites velatus	4									4
Gleicheniidites senonicus	5	+								5
Leiotriletes sp.	6	1.2	0.8					(1)		6
Lycopodiumsporites clavatoides	7									7
Lycopodiumsporites spp.	8									8
Lycospora spp. (R)	9	+								9
Osmundacidites spp.	10									10
Polypodiaceoisporites macrospeciosus	11		+	+						11
Stereisporites spp.	12									12
Taurocusporites segmentatus (R)	13									13
? Tegumentisporis sp.	14	0.4	+	+						14
Triplanosporites sinuosus	15									15
Triquitrites sp. (R)	16									16
Trilete spores undifferentiated	17			0.4			(2)	(1)		17
Reworked trilete spores (undifferentiated)	18									18
Laevigatosporites discordatus	19		1.2	0.4						19
L. haardti	20	+	0.4	0.4		(1)	(1)			20
Laevigatosporites spp.	21									21
Verrucatosporites favus	22									22
Monolete spores (ornamented)	23	0.4								23
Callialasporites dampieri (R)	24									24
Cerebropollenites mesozoicus (R)	25			0.4			(1)			25
Bisaccate pollen	26	2.4	0.8	4.0	9.2	(2)				26
Podocarpidites sp.	27			+						27
Vitreisporites pallidus (R)	28									28
Araucariacites australis	29					(2)	(1)			29
Inaperturopollenites hiatus	30	7.6	4.8	19.2	6.4	(9)	(2)		(2)	30
I. polyformosus	31									31
Inaperturopollenites spp.	32		1.6	2.8	1.2	(46)	(28)	(10)	(12)	32
? Perinopollenites elatoides	33	0.4						(2)		33
Sheripollenites group	34	0.4	0.4							34
Classopollis torosus	35	2.0	+			(2)				35
Eucommiidites spp.	36							(1)		36
Chasmatosporites spp. (R)	37									37
Liliacidites spp.	38			0.4	0.4					38
Milfordia incerta	39		0.4							39
Monocolpopollenites tranquillus	40			+	0.8					40
Monocolpopollenites spp.	41		0.8	0.4	0.8	(1)				41
Ovalipollis ovalis (R)	42									42
liblarensis/microhenrici group	43	0.4	1.6	0.8						43
Cupuliferoidaepollenites cf. liblarensis	44	0.8	0.8	3.2						44
Fraxinopollis variabilis	45	3.2	3.2	2.4	13.2	(1)				45
Retitrescolpites anguloluminosus	46	2.4	2.0	2.4	2.0					46
Tricolpites parvus	47	0.4	+	+	+					47
Tricolpites sp. A	48		0.4	1.2	0.8					48
Tricolpites sp. B	49	1.2	3.2		4.4					49
Tricolpites sp. C	50	+								50
Tricolpopollenites retiformis	51	0.4	2.4	4.0	8.4					51
Tricolpopollenites spp.	52									52
Tricolpate pollen undifferentiated	53	2.0	8.0	4.8	10.4					53
Brevicolpate/colporate pollen	54		5.6							54
? Cyrillaceaepollenites spp.	55		+	1.2						55
Favitricolporites baculoferus	56	+								56
Nyssapollenites sp. A	57			0.8						57
Nyssapollenites sp. B	58									58
Nyssapollenites spp.	59	0.4	0.4	0.4						59
Pentapollenites spp.	60									60

PINCENTS KILN

	SECTION 1						SECTION A		SECTION 2			
	Reading Beds											
	PK17	PK19	PK20	PK21	PK23	PK24	PK4		PK29	PK34	PK35	
1							1.6	1	+		+	1
2						+		2				2
3			+				0.4	3				3
4						+		4				4
5								5				5
6	2	2.0	2.0	2.0	3.2	2.0	1.6	6				6
7				+				7				7
8								8		+		8
9			+				0.4	9				9
10			0.4				0.4	10				10
11			+	+		+	+	11				11
12					+			12				12
13						+		13				13
14	1		1.6	0.8		0.4	1.2	14				14
15			+		+			15				15
16					+			16				16
17	1			2.0		0.4	0.4	17	1.2	1.2	3.2	17
18						0.4		18		1.8		18
19								19			+	19
20	1		0.8	0.8	+	1.2	0.4	20		0.6		20
21								21			0.8	21
22			+	+		0.4	0.8	22		+		22
23								23	0.4	1.2		23
24				+				24				24
25		0.4			0.4		+	25				25
26	4	3.6	4.8	2.0	4.8	1.2	4.8	26	9.2	1.2	2.8	26
27					0.4	+		27			+	27
28			0.4	+		+		28				28
29	1							29	+			29
30	16	10.8	12.8	10.8	30.8	16.0	25.2	30	23.2	9.5	16.8	30
31	1			2.8	1.6	3.6	2.4	31		0.6		31
32	8	4.8	2.4	8.0	4.0	3.6	5.2	32	3.2	8.0	8.0	32
33			0.4	0.8	0.8			33				33
34				0.8		+		34	0.4	+	+	34
35	5	2.0	2.0	1.2	1.6	2.0	0.8	35	2.4		1.2	35
36								36				36
37				+	+	0.8		37				37
38			0.4					38	+		+	38
39				+	+		+	39	0.4			39
40		0.4	1.2		+		0.4	40			4.0	40
41		0.4		0.4	0.4	0.4	1.2	41	1.6		1.6	41
42				+		+		42				42
43	1	1.6	1.6	2.4	2.8	2.0	0.8	43	0.8		2.4	43
44					0.8	0.8	0.8	44	3.6		4.0	44
45	8	4.0	4.8	5.6	4.0	5.6	2.0	45	8.8		1.2	45
46		4.0	0.8	0.8	0.4	0.4		46	1.2	1.2	0.4	46
47	7	+	6.4	6.4	0.8	11.2	10.8	47	1.2	0.6		47
48					0.4			48	1.2			48
49	2		+	+				49		0.6		49
50				1.2		0.8		50				50
51		7.2	5.6	0.4	13.6	1.2	1.6	51	16.4	3.7	20.4	51
52		1.2			+			52				52
53	9	20.0	5.6	8.4	3.2	4.0	2.8	53	5.6	1.2	1.2	53
54								54				54
55		0.4					0.4	55				55
56			0.4	+			0.4	56				56
57			+	0.8	0.4	+	+	57			0.4	57
58		0.4	+	1.2	+	0.4		58				58
59				0.4		0.4	0.4	59				59
60			+	+		+		60				60

TABLE A2.7 continued

		NB1	NB2	WK	KH	M4/7				
						1 *	2 *	3 *	4*	
Rhoipites sp. A	61				1.6					61
Rhoipites sp. B	62	4.0								62
Spinaepollis spinosus	63									63
? Spinulaepollis sp.	64			3.6	2.0					64
Striate tricolpate/tricolporate pollen	65			1.6	0.8					65
Tricolporopollenites aceroides	66									66
T. cingulum	67	7.6		3.2		(1)				67
T. duplibaculatus	68	0.4	0.8	0.4	+	(1)				68
T. iliacus	69									69
T. mansfeldensis	70	16.4	+							70
T. margaritatus	71									71
T. megaexactus	72		0.4							72
T. megareticulus	73		0.8	0.4						73
T. salardae	74		0.4	0.4	1.2					74
T. sittleri	75		0.4	+	+					75
Tricolporopollenites spp.	76	5.2	2.8	3.6	0.4	(1)				76
Cupanieidites sp.	77			0.4	0.4					77
Tetracolporopollenites spp.	78	5.2	0.4	0.4						78
Ericipites sp.	79	+	+							79
Pandaniidites texus	80			+						80
Restioniidites minimus	81									81
R. hungaricus	82									82
Sparganiaceaepollenites cuvillieri	83									83
S. magnoides	84									84
Sparganiaceaepollenites sp. A	85									85
Sparganiaceaepollenites spp.	86			+	0.4					86
Basopollis orthobasalis	87									87
Caryapollenites spp.	88	0.8		0.8						88
C. rhizophorus subsp. rhizophorus	89	1.2	9.6	3.6	+					89
C. rhizophorus subsp. burghasungensis	90	0.4	1.2							90
Compositoipollenites minimus	91	0.8	0.4	0.8	+					91
? Compositoipollenites sp.	92									92
Normapolles undifferentiated	93		0.4	0.4						93
Gallopollis minimus	94	1.6	0.8	0.8	1.6					94
Intratriporopollenites microreticulatus	95	1.6	4.0	3.2						95
I. pseudinstructus	96	4.0	1.6	1.6	0.4					96
Intratriporopollenites sp. A	97	0.4	1.2		0.4					97
Intratriporopollenites spp.	98	0.4	0.4	0.8	2.0					98
M. tenuipolus/M. coryloides	99	1.2								99
Maceopolipollenites rotundus	100	1.6	0.8	1.6	1.2					100
Nudopollis endangulatus/terminalis	101				0.4					101
Platycaryapollenites anticyclus	102									102
P. platycaryoides	103	1.6	1.6	3.6	3.2					103
Plicapollis pseudoexcelsus	104	2.0	3.6	5.6	2.4					104
Plicatopollis spp.	105	0.8	0.4		0.4					105
Pompeckjoidaepollenites subhercynicus	106									106
S. anulatus subsp. anulatus	107									107
S. anulatus subsp. nanus	108				+					108
S. constans subsp. constans	109	+	+		+					109
S. constans subsp. magnus	110									110
S. intrastructurus	111		1.2	0.8	0.8					111
Subtriporopollenites spp.	112		0.4	0.4	0.4					112
Triatriopollenites confusus	113	8.4	13.2	0.8	0.4					113
T. roboratus	114				0.4					114
T. subtriangulus	115		+	0.4	+					115
Triatriopollenites/Momipites spp.	116	5.6	7.2	3.6	8.8		(1)			116
Triporopollenites plektosus	117	0.8	0.8	0.4	2.8					117
T. robustus	118	+	0.4							118
Triporopollenites spp.	119	0.4	2.8	3.2	5.6					119
Trudopollis hammenii	120									120
Vacuopollis sp.	121									121
Alnipollenites trina	122		0.4							122
A. verus	123	0.4		0.4	0.4					123
Erdtmanipollis spp.	124									124
Interpollis messelensis	125									125
I. supplingensis	126									126
Interporopollenites sp.	127			+						127
Panporate pollen undifferentiated	128			0.4						128
Reevsiapollis triangulus	129	0.8	1.2	0.8	+					129
S. hexaradiatus subsp. tribinae	130									130
Ulmipollenites tricostatus	131	0.4			2.4					131
Ulmipollenites spp.	132									132
Others	133	+	2.0		1.2		(4)			133

	PK17	PK19	PK20	PK21	PK23	PK24	PK4		PK29	PK34	PK35	
61	3	0.4	0.4	1.2	0.4	2.0	3.6	61				61
62				1.2				62				62
63							+	63				63
64								64			+	64
65					0.4			65				65
66								66			0.4	66
67		0.4	2.8	4.8	4.4	5.6	5.2	67	0.8	0.6		67
68		+	0.4	+	0.8		0.4	68				68
69						+		69				69
70			0.8	0.4		0.4	+	70				70
71				+	+		+	71				71
72			0.4	2.8	2.0	+		72			0.4	72
73				+				73				73
74		0.4	0.4	+	0.4			74			+	74
75		0.4						75				75
76	1	3.2	5.2	6.8	1.2	4.4	6.4	76	0.8	0.6	3.2	76
77					0.4	0.4		77				77
78	1	0.4	1.6	+	0.4	1.6	0.4	78				78
79			0.4	+	+	+	+	79				79
80		0.4			+			80			+	80
81			1.2	+	0.8	0.4	0.8	81	0.4		+	81
82		1.2				0.4		82				82
83							+	83				83
84				+	+	+	0.4	84				84
85						+		85			+	85
86			+		0.4	+		86				86
87					+			87				87
88			1.2	+			+	88	0.4			88
89		1.6	1.6	+	+	0.4	0.4	89			0.8	89
90			0.4	0.4		+	+	90				90
91		0.4	2.0	+		+		91		0.6		91
92					+	+		92				92
93				0.4	+			93		0.6	+	93
94							+	94	0.4	1.2		94
95	8	3.2	2.0	2.8		0.8	0.4	95	0.4		0.4	95
96		2.4	2.0	0.8	0.8	2.0	2.0	96	0.8		0.4	96
97				+		+	0.4	97	+			97
98	3		1.2	1.2	0.8	1.6	0.4	98		0.6	2.0	98
99	1	1.2		0.4	0.4	0.8	0.4	99	0.8		2.0	99
100	2	0.8	4.4	1.6	0.4	2.0	+	100		1.8	2.0	100
101			+	+		+		101				101
102		+				+		102				102
103	2	2.8	2.0	1.2	2.0	2.0	2.0	103	2.8		2.4	103
104	2	1.6	1.2	1.2	1.6	1.6	1.2	104	1.6	3.1	+	104
105			0.8	0.4		0.8	0.4	105	1.2	0.6	0.4	105
106								106	+			106
107								107	0.4			107
108							0.4	108	+			108
109				+			+	109				109
110					+			110				110
111	1	0.8						111		+		111
112								112				112
113		3.6	3.2	1.2	0.4	2.0	2.4	113	0.4	23.6	1.6	113
114		0.4	0.4	+	0.4	+	+	114				114
115	1	0.4	2.0	1.6	1.6	2.0	0.4	115	0.4			115
116	4	5.6	4.4	4.8	0.8	5.6	1.2	116	4.4	10.6	9.6	116
117			0.4	0.4		0.8	0.8	117		1.2	0.4	117
118			0.8	+	1.2		0.4	118	0.4		0.4	118
119		2.8	0.4	4.0	3.2	2.8	1.6	119	1.6	21.0	2.0	119
120			+					120				120
121				+				121				121
122		0.4		+		0.4		122	+	1.6		122
123			+		+		0.4	123	0.4			123
124							+	124				124
125		0.4			0.4			125				125
126			+					126				126
127								127				127
128								128		0.6		128
129		0.4	+		+		+	129				129
130			+				+	130				130
131		0.4	0.4	+		0.4	0.4	131		0.6	0.4	131
132					0.4	+		132				132
133		1.2	1.2	0.4	+	0.8		133	0.8	0.6	2.8	133

TABLE A2.8 PERCENTAGE OCCURRENCE OF MICROPLANKTON AND OTHER ALGAE IN THE PALAEOCENE SECTIONS FROM THE WESTERN END OF THE LONDON BASIN.

	COLD ASH QUARRY		WATERLOO KILN / KNOWL HILL		M4 MOTORWAY				
	Reading Beds								
					M4/7				
DINOFLAGELLATE CYSTS	NB1	NB2	WK	KH	(1)	(2)	(3)	(4)	
Achomosphaera ramulifera					1.1				1
Areoligera senonensis					3.2				2
Areoligera sp.					3.8	+			3
Areoligera/Glaphrocysta spp.					6.5	28.9			4
Cleistosphaeridium spp.			25.0		5.9	20.3			5
Cordosphaeridium fibrospinosum									6
C. gracilis					0.5				7
C. inodes					0.5				8
Cordoshpaeridium spp.					0.5				9
Glaphrocysta ordinatum					6.5	+			10
Glaphrocysta spp.					5.4	+			11
Gonyaulacysta spp.									12
Homotryblium pallidum						+			13
Homotryblium spp.					0.5	+			14
Hystrichosphaeridium group						17.4			15
Hystrichosphaeridium tubiferum						+			16
Lingulodinium machaerophorum					0.5	+			17
Sentusidinium spp. (R?)					2.6				18
Spiniferites ramosus									19
Spiniferites spp.									20
Dinoflagellates undifferentiated				6.6	10.8	4.3	2.2	16.6	21
ACRITARCHS									
Comasphaeridium cometes					1.1				22
Cymatiosphaera spp.		20.0		23.3	7.0	+	2.8		23
Leiospheres	10.0	20.0		6.6	8.1	4.3	20.2		24
Horologinella spp.									25
Micrhystridium spp.	80.0	40.0	25.0	63.3	32.1	31.9	68.5	83.3	26
Veryhachium spp.						+			27
Acritarchs undifferentiated	10.0		25.0			10.1	5.6		28
OTHERS									
Crassosphaera sp.					1.6				29
Paralecaniella indentata					1.1		0.6		30
Pediastrum sp.			25.0						31
Pterospermella sp.						+			32
Schizosporis parvus		20.0							33
S. spriggi		+						+	34
Botryococcus						+			35
Microforaminiferid linings									36
Total microplankton	10	5	4	30	184	69	178	11	

PINCENTS KILN

	SECTION 1						SECTION A		SECTION 2			
	Reading Beds											
	PK17	PK19	PK20	PK21	PK23	PK24	PK4		PK29	PK34	PK35	
1								1				1
2					+			2				2
3								3				3
4					4.2	+	5.5	4				4
5				+	14.9		11.0	5	2.5			5
6					+		+	6				6
7								7				7
8								8				8
9					+			9				9
10								10				10
11								11				11
12					+			12				12
13								13				13
14								14				14
15		8.3			2.1		5.5	15		3.4		15
16							5.5	16				16
17								17				17
18					4.2	7.1		18				18
19					8.5	7.1	11.0	19				19
20					+			20				20
21	16.6		5.6		+		11.0	21	1.3	10.3	11.0	21
22		8.3			2.1	+	16.5	22	5.2			22
23		16.6			4.2			23	3.9	10.3	22.0	23
24	16.6	16.6	11.1	10.0	8.5			24	5.2	6.9	22.0	24
25				+			5.5	25	9.0			25
26	50.0	16.6	43.3	90.0	44.7	78.6	27.5	26	72.7	68.9	33.0	26
27		8.3	16.7			+		27				27
28		33.2	23.3		4.2	7.1		28		6.9		28
29								29				29
30					+			30				30
31					2.1			31				31
32	16.6							32				32
33			+					33			11.0	33
34			+					34		6.9		34
35	+							35				35
36					+			36				36
	6	12	18	10	47	14	18		77	29	9	

TABLE A2.9 PERCENTAGE OCCURRENCE OF SPORES AND POLLEN IN THE PALAEOCENE AND EARLY EOCENE SECTION AT ALUM BAY, ISLE OF WIGHT.

ALUM BAY

		Oldhaven Fmn.	London Clay Divisions of King 1981							
			A		B			C - D		
		AB45	AB47	AB49	AB50	AB52	AB54	AB55	AB56	AB58	
Smooth trilete spores (undiff.)	1	5.2	6.0	3.6	4.4	4.8	1.2	3.6	5.6	3.2	1
Appendicisporites spp. (R)	2				+						2
Baculatisporites comaumensis	3		+		0.4		0.4	+			3
Camarozonosporites sp.	4					+					4
Cicatricosisporites dorogensis	5		0.4	+	+	0.8	+				5
C. paradorogensis	6					+					6
Cicatricosisporites spp.	7				+					+	7
Contignisporites problematicus (R)	8			+		+	+				8
Coronatispora valdensis (R)	9			+	+	+					9
Densoisporites velatus (R)	10			+	+	+				+	10
Densosporites spp. (R)	11	0.4		+	+	+	+	+			11
Gleicheniidites senonicus	12					+		+	+		12
Klukisporites spp.	13		+		+	+	+				13
Kraeuselisporites reissingeri (R)	14				+		+		+		14
Limbosporites lundbladi (R)	15				+						15
Lycopodiumsporites clavatoides	16			+		+		0.4	0.8		16
Lycopodiumsporites spp.	17			+		+			+		17
Lycospora spp.	18	3.6	1.2	0.8	0.4	+		+	+	0.4	18
Osmundacidites spp.	19	0.4				+		+	0.8		19
Pilosisporites trichopapillosus (R)	20					+	+				20
Polypodiaceoisporites macrospeciosus	21				+		+	0.4	+		21
P. marxheimensis	22			+		0.8	+			+	22
Stereisporites spp.	23	+									23
Taurocusporites segmentatus (R)	24					+					24
?Tegumentisporis sp.	25			+	0.8		0.4				25
Trachysporites fuscus (R)	26						+				26
Trilobosporites spp. (R)	27					+					27
Triquitrites spp. (R)	28			+							28
Uvaesporites argenteaeformis (R)	29		+		+						29
Ornamented trilete spores	30	1.6	2.0	1.2	1.2	1.6	2.8	2.0		0.8	30
Reworked spores undifferentiated	31			0.4		+			0.4		31
Laevigatosporites discordatus	32										32
L. haardti	33	0.4	0.4	0.8	0.8	0.4	0.8		0.4	+	33
Verrucatosporites favus	34					+	+		+		34
Ornamented monolete spores	35		0.8	0.8	0.4	1.2		1.6	1.2		35
Callialasporites dampieri (R)	36		1.2	+	0.8	+	0.4	0.4	0.4		36
C. trilobatus (R)	37			+	+	+	+		+	+	37
Inaperturopollenites turbatus (R)	38	0.4	+	+	+	+	+		+		38
Cerebropollenites mesozoicus (R)	39	1.6	2.0	0.4	2.0	1.2	1.2	0.8	2.0	+	39
Bisaccate pollen undifferentiated	40	9.2	7.6	6.4	11.2	8.4	4.0	10.0	6.0	2.0	40
Parvisaccites radiatus (R)	41	0.8	0.4	0.8		+		+			41
Podocarpidites spp. (?R)	42		+			+		+	0.4		42
Quadraeculina anellaeformis (R)	43	1.6	+	+	+		+		+		43
Vitreisporites pallidus (R)	44	0.4	0.4	2.4	+	0.4	1.2	+	0.4	+	44
Araucariacites australis (R)	45		+	0.4	1.2		0.4	0.8			45
Inaperturopollenites hiatus	46	6.0	14.0	11.2	25.2	13.6	26.4	15.6	13.6	7.6	46
I. polyformosus	47										47
Inaperturopollenites spp.	48	22.0	8.0	8.0	5.2	4.0	7.6	13.2	8.8	4.0	48
?Perinopollenites elatoides	49	8.8	3.2	2.8	12.0	0.8	2.4	2.0	2.8		49
Spheripollenites group	50	4.8	11.2	13.2	4.4	8.0	4.4	10.0	13.2	4.0	50
Classopollis echinatus (R)	51				0.4						51
C. torosus (R)	52	9.2	4.8	11.6	7.6	6.0	2.4	6.0	14.0	4.4	52
Granuloperculatipollis rudis (R)	53				+						53
Rhaetipollis germanicus (R)	54	+		+	+						54
Eucommiidites spp.	55		0.4	+		+	0.4	0.8			55
Chasmatosporites spp. (R)	56		0.8	0.4	+	+	0.4	+	0.8		56
Clavatipollenites spp.	57							+		+	57
Liliacidites spp.	58			0.4			+	+		2.4	58
Milifordia incerta	59										59
Monocolpopollenites tranquillus	60	0.4		+		2.0	0.4		0.8	3.2	60
Monocolpopollenites spp.	61	3.2	0.4		1.6	2.4		0.8	1.2		61
Ovalipollis ovalis (R)	62			+	+		0.4				62
Riccisporites tuberculatus (R)	63		+	+	+	+	+		0.4		63
Spinizonocolpites spp.	64						+			0.4	64
Disulcites spp.	65					+	0.8			4.4	65
Cornaceoipollenites parmularius	66			0.4	0.4						66
liblarensis/microhenrici group	67	0.8	2.0	1.6	2.0	5.6	1.6	0.4	1.6	2.4	67
Cupuliferoidaepollenites cf. liblarensis	68	0.4		0.4	0.8			0.8		2.8	68
Fraxinopollis variabilis	69	1.2	1.6	2.4	0.4	2.8	2.8	2.0	0.8	2.0	69
Retitrescolpites angulovuminosus	70		0.8	0.4			0.4				70
Tricolpites parvus	71	1.2	0.8	0.8	+	0.4	0.4	3.6			71
Tricolpites sp. A	72						0.4				72

ALUM BAY

	BRACKLESHAM BEDS						
	Eaton's Beds				? Fisher's Beds		
	1	2			IV	VIII	
	AB57	AB60	AB63	AB64	AB68	AB70	
1	2.8	2.4	0.4	1.6	2.0	2.0	1
2							2
3					+		3
4			+	+	0.4		4
5				+			5
6					+		6
7							7
8							8
9	+						9
10							10
11	0.4						11
12							12
13							13
14							14
15							15
16	+						16
17							17
18	1.2						18
19						+	19
20							20
21		0.4		+		+	21
22	0.8		+				22
23				+			23
24							24
25							25
26							26
27							27
28							28
29							29
30					0.4		30
31	+						31
32			0.4	0.4			32
33	0.8	+		1.6	0.8	0.8	33
34			0.4	0.8	0.4	+	34
35	2.0	0.4	0.4				35
36							36
37							37
38							38
39							39
40	1.2	3.2			1.2	+	40
41							41
42		+					42
43							43
44							44
45	0.4						45
46	9.6	8.8		1.2	0.4	+	46
47				+	0.4	0.4	47
48		2.8	0.8	2.4	0.8	0.8	48
49						0.4	49
50	2.4	3.2					50
51	0.8						51
52	0.8	0.4		+	0.4	0.4	52
53							53
54							54
55	0.4						55
56							56
57	+						57
58	2.0	3.2	0.8	0.4	0.4		58
59	0.4	1.6			+		59
60	1.2	2.4	6.0	4.4	6.4	5.6	60
61	0.4	0.4		2.4		0.8	61
62							62
63							63
64	1.2	0.8	+	0.4	0.4	+	64
65	2.4	+	2.4	1.6	1.2	1.2	65
66	0.4						66
67	8.8	16.4	18.0	16.4	16.8	4.8	67
68	4.8	3.6	1.6	2.8	1.2	0.8	68
69	1.6	2.8	4.0	1.2	0.4	0.4	69
70		0.4			0.4		70
71		0.4		+	0.8	0.4	71
72			0.4	0.4	0.4		72
73				0.4			73
74	1.6	1.6	1.2	0.4	0.4	0.4	74

TABLE A2.9 continued

		AB45	AB47	AB49	AB50	AB52	AB54	AB55	AB56	AB58	
Aesculiidites circumstriatus	76									+	76
Brevicolpate/colporate pollen	77						0.8	0.8	2.4	+	77
Favitricolporites baculoferus	78							0.4			78
Margocolporites lihokus	79		+					+		0.4	79
Nyssapollenites spp.	80					0.4	+			0.8	80
Pentapollenites spp.	81							0.4		+	81
Rhoipites sp. A	82			0.4			0.4			0.4	82
Rhoipites sp. B	83						+			+	83
Striate tricolpates/tricolporates	84						0.4		0.4	1.2	84
Tricolporopollenites aceroides	85					1.2				+	85
T. cingulum	86	2.8	12.4	10.0	6.0	19.6	13.2	11.6	9.2	12.0	86
T. aff. cingulum	87										87
T. duplibaculatus	88			0.8	0.4	0.8				+	88
T. iliacus	89			+						+	89
T. kruschi	90						+				90
T. margaritatus	91									1.6	91
T. megaexactus	92	0.8	1.2	0.8	0.4	2.0	2.4	0.8	0.8	1.6	92
T. megareticulus	93		0.4	0.4							93
T. salardae	94						0.4	0.4		+	94
T. cf. sittleri	95									0.8	95
Tricolporopollenites sp. A	96										96
Tricolporopollenites spp.	97	2.4	3.6	2.4	0.4	1.2	3.2	2.4	2.0	5.2	97
Cupanieidites spp.	98									0.4	98
Duplopollis myrtoides	99										99
Tetracolporopollenites spp.	100						1.2			0.8	100
Polycolpites sp.	101						+				101
Ericipites sp.	102					0.4					102
Pandaniidites texus	103			0.4							103
Restioniidites minimus	104										104
R. hungaricus	105									0.8	105
Sparganiaceaepollenites magnoides	106									1.6	106
S. reticulatus	107										107
S. sparganioides	108					+	0.4				108
Sparganiaceaepollenites spp.	109		0.4					+			109
Diporites iskaszentgyorgii	110									+	110
Brosipollis striatobossus	111										111
Caryapollenites spp.	112	0.4		+	+	0.4	0.4	0.4		+	112
Compositoipollenites rhizophorus ss.	113					+	0.4				113
C. rhizophorus burghasungensis	114						+				114
C. minimus	115						+			+	115
?Compositoipollenites sp.	116	0.8		+		+	+			0.4	116
Extratriporopollenites spp.	117										117
Gallopollis minimus	118									0.4	118
Intratriporopollenites microreticulatus	119					+	0.8			+	119
I. pseudinstructus	120			0.4			+		0.4	+	120
Intratriporopollenites sp. A	121					0.4				+	121
Intratriporopollenites spp.	122	0.4							0.4	0.4	122
Labrapollis globosus	123										123
L. labraferus	124		0.4								124
Maceopolipollenites rotundus	125									+	125
M. tenuipollus/Momipites coryloides	126										126
Momipites quietus	127										127
Nudopollis endangulatus/terminalis	128										128
Pistillipollenites mcgrgorii	129			0.4			0.4			+	129
Platycaryapollenites platycaryoides	130	2.0	2.0	1.2	1.6	2.0	3.6	0.8	2.0	4.0	130
Plicapollis pseudoexcelsus	131		0.8	1.2	+	0.4	0.4			4.4	131
Plicatopollis spp.	132	0.4	0.8	0.4	0.4		0.4	0.4		2.4	132
Pompeckjoidaepollenites subhercynicus	133			+	0.4	+	0.4				133
Subtriporopollenites anulatus	134				+						134
S. constans sl.	135										135
S. intrastructurus	136		0.4		0.4	0.8	0.8	0.4		0.4	136
Subtriporopollenites spp.	137									0.4	137
Thomsonipollis magnificus	138										138
T. magnificoides	139										139
Triatriopollenites roboratus	140		0.4			+					140
Triatriopollenites spp.	141	1.2	0.8	1.2	1.6	0.8	1.6	1.2	0.4	3.2	141
Triporopollenites plektosus	142			0.8				0.8	0.4	0.8	142
T. robustus	143		0.4	0.4					0.4	0.8	143
Triporopollenites spp.	144	0.8	0.4	0.4	1.6	0.8	0.8	0.4	0.8	2.4	144
Alnipollenites trina	145	0.4									145
Alnipollenites verus	146						+		+		146
Anacolosidites pseudoefflatus	147										147
Interpollis messelensis	148										148
I. suplingensis	149			+		0.4				2.0	149
I. velum	150				0.4					0.4	150
?Nothofagidites sp.	151						+			+	151
Parsoniidites britanicus	152										152
Polyatriopollenites stellatus	153										153
Reevsiapollis triangulus	154										154
Ulmipollenites tricostatus	155	0.8	1.2	+	0.8	0.8	0.4	0.4	0.8	2.4	155
Others	156			0.8		1.2		1.2	0.4		156

	AB57	AB60	AB63	AB64	AB68	AB70	
76							76
77	+	+		+	+	0.4	77
78			0.4	0.4			78
79							79
80	+		0.8	0.8	0.4	0.8	80
81	1.2				+	1.2	81
82					+		82
83	+						83
84	0.4	1.2			0.4		84
85					0.4		85
86	2.0	5.6	7.2	16.8	20.0	18.8	86
87				0.4	2.8	20.4	87
88				0.4		0.8	88
89	+	0.8	0.4	1.6	0.8	0.8	89
90		+		+		1.2	90
91	4.0	0.8	0.4	0.4			91
92	0.8	0.8	1.2	1.2	5.6	4.8	92
93							93
94	0.4	2.4	2.4		0.4	1.2	94
95	0.4	0.4	+	0.4		1.2	95
96		+	+				96
97	3.2	2.4	5.2	5.2	6.4	2.4	97
98						0.8	98
99				0.8		0.4	99
100	0.4	+	0.4	3.2	2.8	1.6	100
101							101
102							102
103			0.8				103
104	0.4			0.4	1.6		104
105	1.6	+	0.4	1.6	0.4	+	105
106	0.8						106
107					0.4		107
108							108
109	2.4			0.4	0.8		109
110				+	+		110
111		+					111
112	0.4	0.4	+	0.4		0.4	112
113	0.8				+	+	113
114					0.4		114
115					+		115
116	0.8	1.2	1.6	2.0	0.4	+	116
117			+	0.8	0.4		117
118		0.8	2.4	0.4	1.2	0.4	118
119						+	119
120	+	0.8			+	0.4	120
121							121
122				0.8			122
123						0.8	123
124	0.4						124
125		0.4	0.4		1.6	4.4	125
126		0.4					126
127					0.4	3.2	127
128		+	8.8	4.4	0.8		128
129	+	0.4				+	129
130	3.6	3.6		0.8	0.4		130
131	13.2	2.0	2.8	2.8	1.6	0.8	131
132	0.8	+		+	0.4		132
133		+	8.0	0.8	0.8	+	133
134			0.8				134
135						+	135
136	1.2	0.8	0.4		1.2	1.2	136
137		0.8			0.4		137
138		+					138
139		+					139
140							140
141	0.8	2.0	1.2	2.4	1.2	5.2	141
142	0.4	+	0.4	0.4		0.4	142
143		+	2.4	1.2	0.8	+	143
144	1.2	2.8	5.2	3.2	3.2	2.0	144
145		0.4		+			145
146	0.4	+					146
147		+					147
148	0.8	+					148
149	2.8	+	+	+			149
150							150
151	+	+		+			151
152					+		152
153						+	153
154				0.4		+	154
155	0.8	0.8		0.4	0.4	0.8	155
156	0.4	0.8	2.0	0.4	1.2	1.2	156

TABLE A2.10 PERCENTAGE OCCURRENCE OF MICROPLANKTON AND OTHER ALGAE IN THE PALAEOCENE AND EARLY EOCENE SECTION AT ALUM BAY, ISLE OF WIGHT.

ALUM BAY

		Oldhaven Fmn.	London Clay Divisions of King 1981								
			A		B				C - D		
		AB45	AB47	AB49	AB50	AB52	AB54	AB55	AB56	AB58	
DINOFLAGELLATE CYSTS											
Achomosphaera spp.	1					+					1
Adnatosphaeridium aemulum (R)	2			+							2
A. caulleryi (R)	3							+			3
A. reticulense	4						+				4
A. robustum	5					+					5
? Adnatosphaeridium patulum	6						+				6
Apectodinium homomorphum	7					+	+		+	+	7
Apectodinium spp.	8				+	+	+				8
Apteodinium granulatum (R)	9								+		9
Areoligera spp.	10					+				+	10
Areoligera/Glaphrocysta spp.	11	1.1	1.3		+					2.8	11
Athigmatocysta glabra (R)	12			+							12
Cleistosphaeridium spp.	13	3.4	3.8	6.6	7.1	12.8	8.2	7.8	3.3	11.0	13
Cordosphaeridium spp.	14		1.3		+		+			+	14
Cribroperidinium spp. (R)	15					+	+	+			15
Ctenidodinium elegantulum (R)	16			+		+					16
Ctenidodinium spp.	17				1.4				+		17
Cyclonephelium distinctum (R)	18	+				+		+			18
Deflandrea phosphoritica	19					+		+			19
Deflandrea spp.	20										20
Dingodinium albertii (R)	21	+				+		+			21
Dracodinium solidum	22					+	+				22
Dyphes colligerum	23					+	+				23
Gardodinium trabeculosum (R)	24			+					+		24
Glaphrocysta ordinata	25			+	+			+		+	25
Glaphrocysta spp.	26				1.4					11.0	26
Gonyaulacysta ambigua (R)	27				+						27
G. jurassica (R)	28		+								28
G. longicornis (R)	29						+				29
Gonyaulacysta spp.	30			+	1.4	+	+		+		30
Hafniasphaera spp.	31		+		+				3.3	+	31
Homotryblium pallidum	32					+					32
Homotryblium spp.	33										33
Hystrichodinium voigtii (R)	34							+			34
Hystrichokolpoma spp.	35									+	35
Hystrichosphaeridium tubiferum	36			+			+				36
Hystrichosphaeridium spp.	37		1.3	3.3		3.2	2.7				37
Kisselovia tenuivirgula	38										38
Lingulodinium machaerophorum	39									+	39
? Microdinium sp. 2 Sch.-L. & Ch.	40									+	40
Microdinium spp.	41	5.6			1.4	12.8	2.7				41
Nannoceratopsis gracilis (R)	42						+				42
Operculodinium centrocarpum	43		+		+	+	+			+	43
Polysphaeridium subtile	44						+			+	44
Prolixosphaeridium spp.	45	1.1	+			3.2					45
Sentusidinium spp.	46	3.4	1.3	6.6	2.9	6.4	+	3.9			46
Spiniferites cingulatus	47				+	+					47
S. ramosus	48		1.3	+		+				+	48
Spiniferites spp.	49			+		+	+				49
Dinoflagellates undifferentiated	50	10.1	6.3	3.3	1.4	3.2	5.5		6.6	2.8	50
ACRITARCHS											
Comasphaeridium cometes	51	+	2.5	3.3	2.9						51
Cymatiosphaera spp.	52	6.8		6.6	1.4	3.2	2.7		3.3		52
Leiofusa jurassica (R)	53	1.1			1.4				+		53
Leiospheres	54	19.2	6.4	3.3	17.3	9.6	8.3	19.6	16.7	13.8	54
Micrhystridium spp.	55	33.0	64.1	59.9	54.9	41.8	66.6	60.7	66.6	58.2	55
Veryhachium spp.	56	3.4	10.2		4.3	3.2	2.7	3.9			56
Acritarchs undifferentated	57										57
OTHER ALGAE											
Crassosphaera sp.	58	1.1		3.3	+	+		1.9			58
Tasmanites sp.	59				+	+		1.9			59
Paralecaniella indentata	60	7.9		3.3						+	60
Pediastrum sp.	61										61
Pterospermella spp.	62	2.3						+			62
Ovoidites ligneolus	63										63
Schizosporis sp.	64										64
Botryococcus sp.	65			+	+	+			+		65
Total microplankton		88	78	30	69	31	36	51	30	36	

ALUM BAY

	Bracklesham Beds						
	Eaton's Beds				Fisher's Beds		
	1	2			IV	VIII	
	AB57	AB60	AB63	AB64	AB68	AB70	
1							1
2							2
3							3
4							4
5							5
6							6
7					+		7
8	14.7						8
9							9
10		6.6					10
11							11
12							12
13	11.6	6.6			+	33.3	13
14	2.9						14
15							15
16							16
17							17
18							18
19							19
20					+		20
21							21
22							22
23							23
24							24
25	26.4				+		25
26	2.9	+					26
27							27
28							28
29							29
30	2.9						30
31							31
32							32
33					+		33
34							34
35							35
36							36
37	2.9	+					37
38						+	38
39							39
40	2.9						40
41	2.9						41
42							42
43	+						43
44							44
45							45
46							46
47							47
48					+		48
49							49
50	2.9				28.5	33.3	50
51							51
52		6.6					52
53							53
54	8.8	20.0		57.1	14.2	33.3	54
55	14.5	33.4	100.	14.2	57.2		55
56							56
57							57
58		6.6					58
59							59
60	+						60
61		6.6					61
62							62
63	2.9			28.5			63
64		13.3					64
65							65
	34	15	1	7	7	3	